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FIRE SEASON CLIMATIC ZONES OF MAINLAND ALASKA

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ABSTRACT

Calculated values of precipitation effectiveness index and temperature efficiency index for 48 weather observation stations on the Alaska mainland are used to delineate areas that have different climatic subclassifications during the wildfire season of April through September. The paper outlines procedures, provides maps showing step-by-step analysis along with the resulting areal boundaries, and suggests possible uses of the information.

Keywords: Climatology, fire prevention.

ACKNOWLEDGMENTS

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INTRODUCTION

The fire weather forecaster's area of interest in the climate of Alaska is the Alaska mainland--that part of the State lying between the Canadian border on the east and the Bering Sea on the west and between the Brooks Range on the north and the Gulf of Alaska on the south. A major problem in making forecasts for this area, however, is that the only classifications of climate hitherto available have shown broad categories, each containing wide ranges of precipitation and temperature. Furthermore, all the classification systems have been based on annual values of these parameters. The climatological regions of mainland Alaska were described by Watson[1/] as four zones:

1. A zone dominated by maritime influences, which would include the north coast of the Gulf of Alaska.

2. A zone of transition between maritime and continental climatic influences.
   a. The Copper River basin.
   b. Cook Inlet.
   c. West-central area--southern Seward Peninsula and the deltas of the Yukon and Kuskokwim Rivers.

3. A zone dominated by continental climatic influences, referred to as the interior basin.

4. A zone of dominant arctic influences, referred to as the Arctic drainage.

Other climatological systems, among them those of Fitton,[2/] U.S. Department of Agriculture,[3/] and U.S. Army Air Force,[4/] display similar classification patterns. Thornthwaite[5/] categorized the climate of mainland Alaska into two types--taiga and tundra, both moisture

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[1/] D. C. Watson. Climate of the States - Alaska. Weather Bur., U.S. Dep. Commer. Climatography of the United States No. 60-49, 8 p., 1959.

[2/] Edith M. Fitton. The climates of Alaska. Mon. Weather Rev. 58(3): 85-103, illus., 1930.

[3/] U.S. Department of Agriculture. Climate and man, yearbook of the Department of Agriculture. Washington, D.C. 1,248 p., illus., 1941.

[4/] U.S. Army Air Force. Climatic atlas for Alaska. Weather Inform. Br. Rep. 444, 229 p., 1943.

[5/] C. Warren Thornthwaite. The climates of North America according to a new classification. Geogr. Rev. 21: 633-655, illus., 1931.

deficient--on the basis of calculated values of precipitation effectiveness index (PEI) and temperature efficiency index (TEI), which integrate temperature and precipitation. All these classification systems are acceptable for general climatic considerations but lack sufficient detail to be of value for forecasting for a single-season activity such as fire control. These broad climatic regimes in Alaska can be subdivided into smaller areas of reasonably homogeneous climate. The objective of this report, therefore, is to outline more specifically the fire-season climatic zones of the Alaska mainland.

SCOPE

The scope of this report is that afforded by available climatic data. These data consist of observations of temperature and precipitation from 48 weather observation stations, as listed in table 1 and shown on figure 1, operated by the Bureau of Land Management, the Federal Aviation Administration, the U.S. Air Force, the National Weather Service, and the Alaska State Highway Department, for the months of April through September, 1956 through 1965. The restriction limiting the stations to mainland Alaska serves to exclude the Arctic Slope, the Aleutian Island chain, and the Alaska Panhandle southeast of Yakutat, but encompasses the portions of the State that are chiefly affected by wildfires.

This report is intended to provide a "first look" at some of the differences that exist in what can be called fire weather climate classifications.

METHODS

Thornthwaite's PEI and TEI were selected as the basis of the climatic subclassification because large quantities of data were involved; and since the calculation of PEI and TEI is entirely numerical, computer techniques were easily applied. Minor modifications were made to Thornthwaite's procedures. Maximum daily temperature was used in this study because it was the only data available. This use of maximum daily temperature does not change the relationships between the various climatic subclassifications which are only relative. Thornthwaite's precipitation index is

$$I = \sum_{n=1}^{12} 115 \left(\frac{P}{T-10} \right)_n^{\frac{10}{9}} \qquad (1)$$

where P is the normal monthly precipitation in inches and T is the normal monthly temperature in degrees F. ($T < 28.4^{\circ}$F. $= 28.4^{\circ}$F.).

For the purpose of this study, Thornthwaite's formulas 1 and 3 were modified. PEI and TEI as used in this study are average values for the

Table 1.--*Station values of the precipitation effectiveness index and the temperature efficiency index for the stations used in the report*

Station number,[1] name, and agency[2]	Station precipitation effectiveness index (PEI)	Station temperature efficiency index (TEI)	Data base, number of months (M)
1. Allakaket, NWS Climat	15.5	20.8	54
2. Anchorage, NWS	17.6	21.0	60
3. Aniak, NWS	22.1	20.3	48
4. Bethel, NWS	23.7	16.3	60
5. Bettles, FAA	14.5	21.6	60
6. Big Delta, FAA	15.5	20.8	60
7. Cape Newenham, USAF	43.3	13.0	43
8. Cape Romanzof, USAF	43.7	11.2	57
9. Chitina, NWS Climat	7.5	23.5	46
10. Circle Hot Springs, NWS Climat	12.4	23.4	60
11. Dillingham, NWS	26.7	21.2	57
12. Eagle, NWS Climat	11.7	21.2	54
13. Eielson Air Force Base, USAF	15.2	23.6	57
14. Fairbanks, NWS	11.8	22.8	60
15. Farewell, NWS	25.2	17.6	60
16. Flat, NWS Climat	14.7	22.7	30
17. Fort Yukon, NWS	7.7	20.8	58
18. Galena, USAF	19.4	19.3	60
19. Gulkana, NWS	12.7	22.0	60
20. Holy Cross, NWS Climat	20.5	21.3	60
21. Homer, NWS	21.2	18.1	60
22. Hughes, NWS Climat	18.7	19.8	54
23. Iliamna, NWS	33.9	17.8	60
24. Kenai, FAA	24.2	18.4	60
25. King Salmon, NWS	20.3	20.5	60
26. Kotzebue, NWS	15.2	13.3	60
27. Lake Minchumina, NWS	20.0	19.7	60
28. Manley Hot Springs, NWS Climat	16.7	25.0	59
29. McGrath, NWS	19.7	20.0	60
30. Moses Point, FAA	24.2	16.4	60
31. Nenana, FAA	14.8	21.9	60
32. Nome, NWS	22.0	14.2	60
33. Northway, FAA	13.6	21.1	58
34. Palmer, FAA	14.8	23.7	53
35. Paxson, NWS Climat	30.0	18.2	26
36. Puntilla, NWS Climat	15.2	17.8	56
37. Sheep Mountain, NWS Climat	17.0	19.7	52
38. Slana, NWS Climat	21.0	24.9	46
39. Sleetmute, BLM	20.6	20.6	35
40. Sparrevohn, USAF	29.2	17.3	35
41. Summit, NWS	28.6	14.4	60
42. Talkeetna, FAA	32.4	22.3	60
43. Tanacross, BLM	10.6	25.3	46
44. Tanana, FAA	19.3	20.7	60
45. Tok, NWS Climat	7.4	24.5	53
46. Trim's Camp, ASHD	41.8	17.5	55
47. Unalakleet, FAA	27.3	14.6	60
48. Utopia Creek, USAF	18.7	19.8	60

[1] Keyed to location of station on figure 1.

[2] Source of data: NWS Climat = National Weather Service Climatological Station
NWS = National Weather Service Observation Station
BLM = Bureau of Land Management Fire Weather Station
USAF = U.S. Air Force Weather Station
FAA = Federal Aviation Administration Station
ASHD = Alaska State Highway Department Station

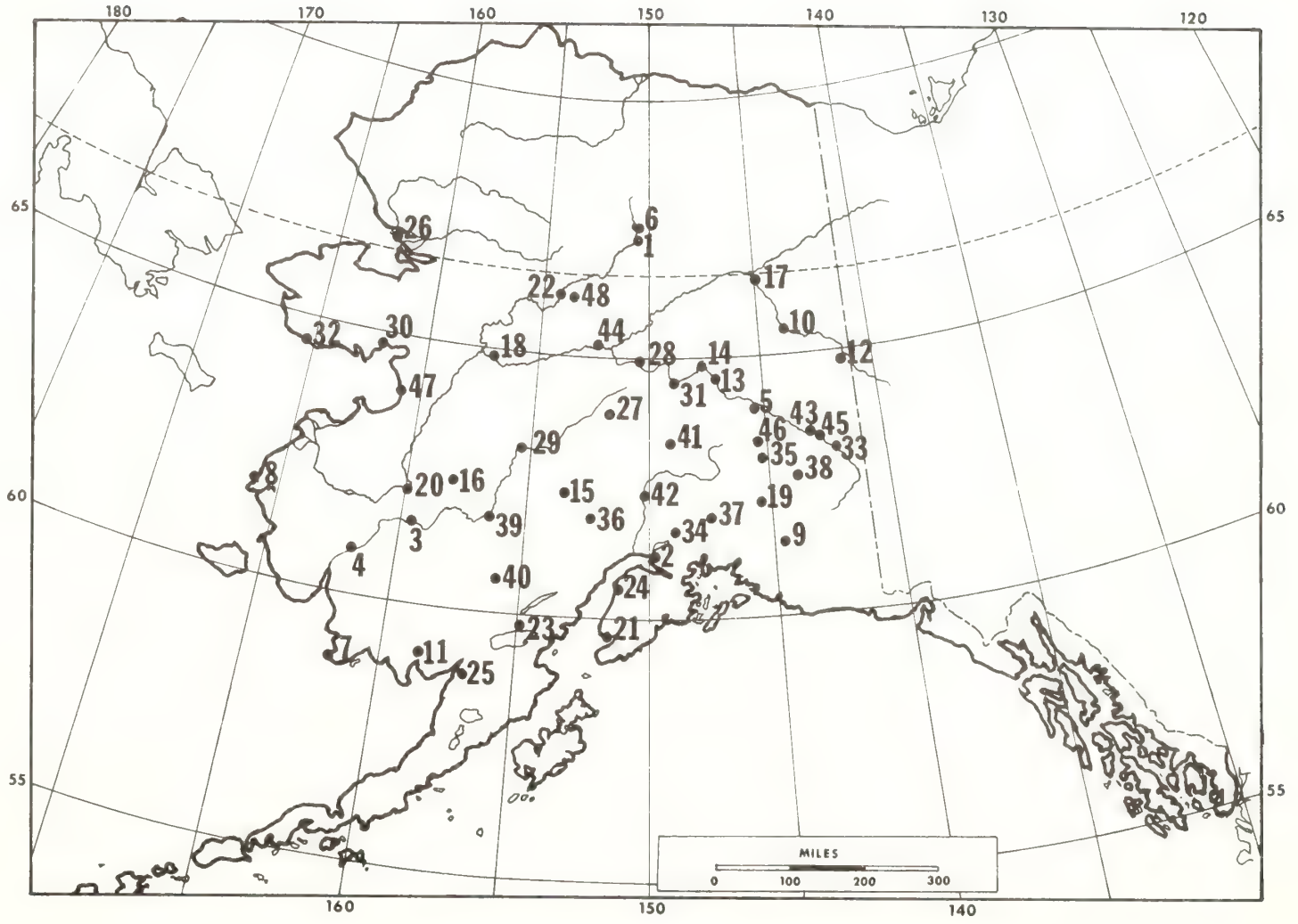

Figure 1.—Location of weather stations used as data source for this study.

6-month fire season of April-September covering the period of record as shown in table 1.

$$PEI = \left[\frac{\sum_{n=1}^{M} 115 \left(\frac{P'}{T'-10} \right)_n^{\frac{10}{9}}}{M} \right] 6 \qquad (2)$$

where P' is the total precipitation for each month, T' is the mean maximum daily temperature for each month in degrees F. ($T' < 28.4^{\circ}F. = 28.4^{\circ}F.$) and M is the number of months of data.

Thornthwaite's temperature efficiency index is:

$$I' = \sum_{n=1}^{12} \left(\frac{T-32}{4} \right)_n \qquad (3)$$

where T = normal monthly temperature values in degrees F. ($T < 32^{\circ}F. = 32^{\circ}F.$). Formula 3 was also modified for the purpose of the study. The modified version of the formula is:

$$TEI = \left[\frac{\sum_{n=1}^{M} \left(\frac{T'-32}{4} \right)_n}{M} \right] 6 \qquad (4)$$

where T' is the mean maximum daily temperature for each month in degrees F. ($T' < 32^{\circ}F. = 32^{\circ}F.$) and M is the number of months of data used.

Maximum daily temperature, which usually occurs about 1400 local standard time, is used to calculate the values of PEI and TEI. Landsberg[6/] gives the approximate optimum length of record for observations of temperature for plains and mountainous terrain in tropical regions as 15 to 20 years; for humidity, the period is 5 to 10 years; and for rainfall, 40 to 50 years. In the area of Alaska, no stations being considered had 50 years of data as of 1965, and only four stations had data for 40 years. A total of 17 stations had data for 25 years. In order to obtain as dense a network of data as possible, the time period for the report was fixed at 10 years. This represents a compromise. High network density with short-term records was considered more important than the need for the smoothing effect produced by use of low network density with long-term records.

6/ H. E. Landsberg and W. C. Jacobs. Applied climatology. *In* Compendium of meteorology, p. 976-992. Baltimore: Waverly Press, Inc., 1960.

A computer program was written to calculate the PEI and TEI for each month of the fire season period of April through September, 1956 through 1965, for each of the 48 stations. The monthly values were added to produce 10 seasonal values, from which a seasonal average was calculated to produce PEI and TEI values for the station (table 1). The mean and the standard deviation of PEI and TEI values for the 48 stations were then calculated. For TEI, the mean is 19.8 and the standard deviation is 3.3. For PEI, the mean is 20.4 and the standard deviation is 8.6. Station values of PEI and TEI were then plotted separately on two maps and isolines drawn (figs. 2 and 3) for the following intervals: at the mean, at one standard deviation above the mean, and at one standard deviation below the mean. Thus each map appeared with four classes of areas as described in table 2.

Table 2.--*Names and class limits of precipitation effectiveness index and temperature efficiency index in climatic zones*

Item	PEI name	Class limits	TEI name	Class limits
$>(\bar{X} + \sigma)$	Wet	>29.0	Hot	>23.1
$\bar{X}$ to $(\bar{X} + \sigma)$	Moist	20.4-29.0	Warm	19.8-23.1
$\bar{X}$ to $(\bar{X} - \sigma)$	Dry	11.8-20.3	Cool	16.5-19.7
$<(\bar{X} - \sigma)$	Arid	<11.8	Cold	<16.5

For the PEI, the classes were: an arid area encompassing those regions where the value of PEI fell beyond one standard deviation below the mean, a dry area where the PEI fell between the mean and one standard deviation below the mean, a moist area where the PEI fell between the mean and one standard deviation above the mean, and a wet area where the PEI was beyond one standard deviation above the mean. In a similar manner, the TEI map was divided into cold, cool, warm, and hot areas.

Mean and standard deviation of the station values were used to provide cutoff points for segregating the different areas in order to make the end product of this investigation, the bounding of areas of different climate, as objective as possible. It was soon recognized that much of the map analysis and the final decisions as to exact placement of the boundary lines between areas with different climatic regimes were bound to be subjective. The simplest example of this is the question of which side of a range of hills a line should be placed dividing two areas of radically different

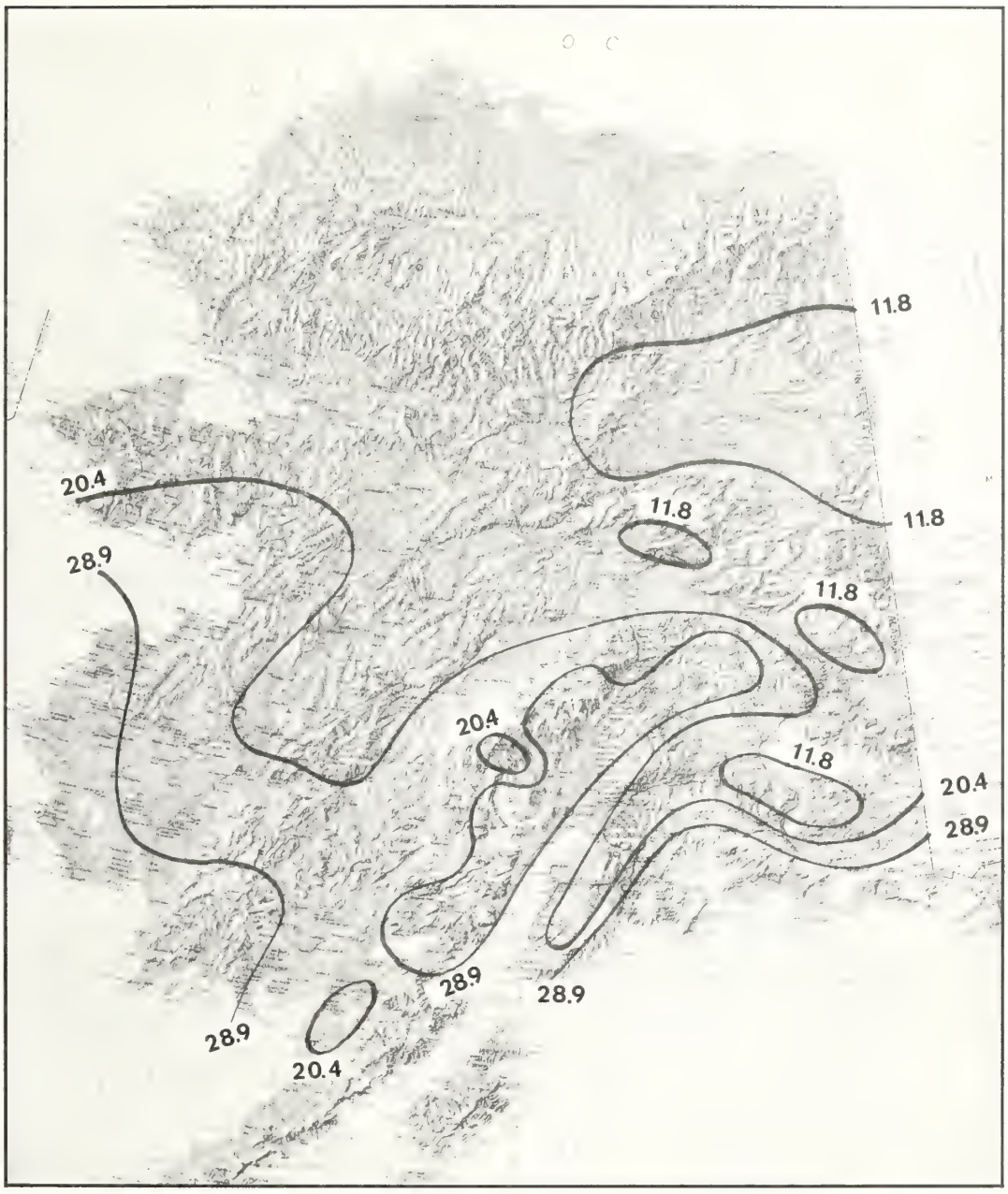

Figure 2.—Map of Alaska with isoline analysis of PEI. Isolines are drawn for the mean and for one standard deviation above and below the mean.

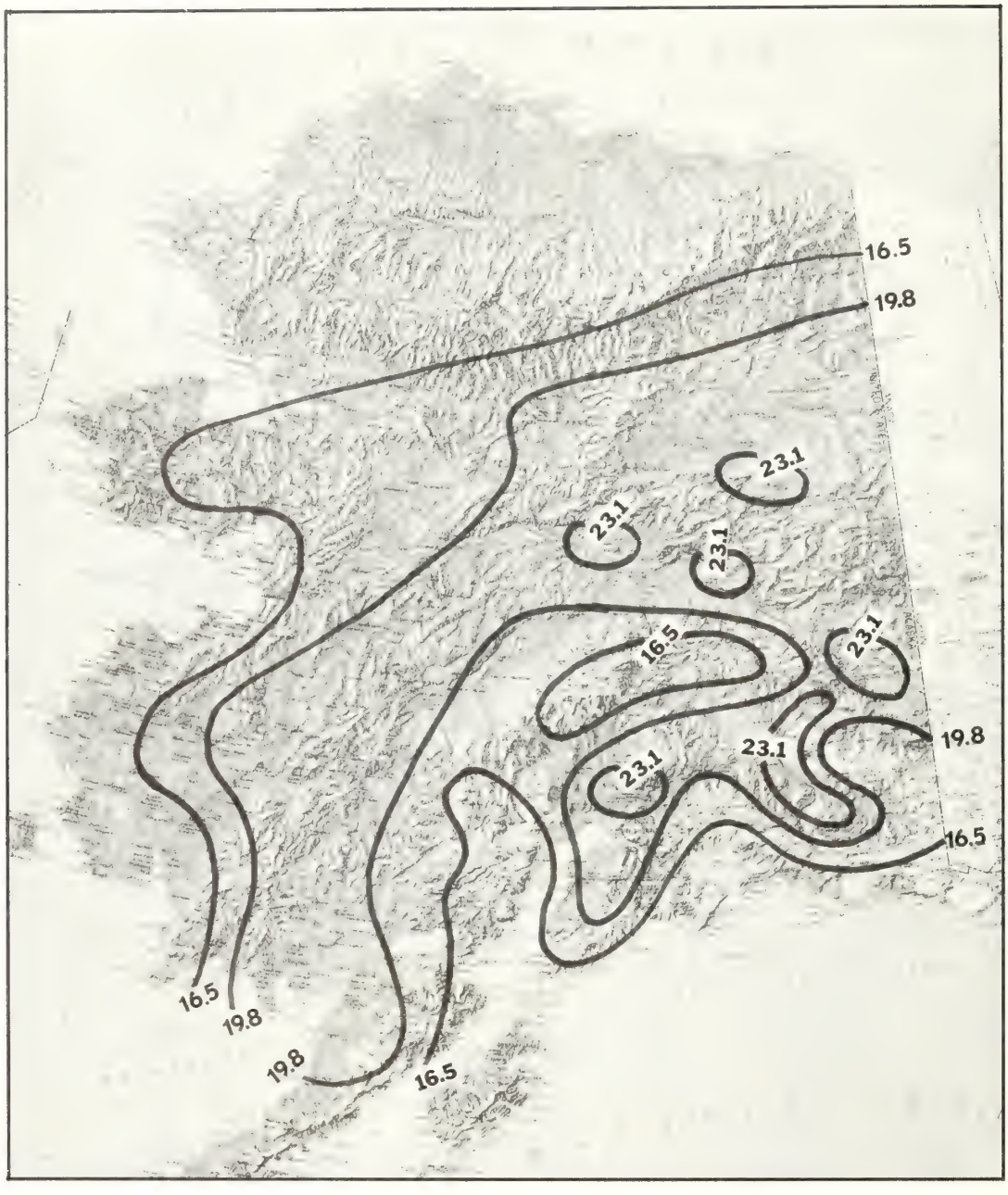

Figure 3.—Map of Alaska with isoline analysis of TEI. Isolines are drawn for the mean and for one standard deviation above and below the mean.

temperature--in the absence of data, how do you tell? Use of the mean and the standard deviation gave a consistent and reasonably objective foundation on which the analysis could be based, however, and narrowed the amount of subjectivity that had to be tolerated.

The next procedure was to superimpose one map above the other and draw all the lines from both maps onto a third composite map (fig. 4), so that any portion of the State could be referred to as one of the 16 combinations of TEI and PEI (fig. 5). An exact rendering of this composite map produced over mainland Alaska thus outlined 44 areas, for each of which it could be said that the climatic conditions varied from those of the surroundings. Some of these areas were enormous, but many were small and frequently were sharply elongated where the isolines on the PEI and TEI maps were essentially parallel to each other (fig. 4).

The next step was to consolidate these small and irregularly shaped areas with other areas nearby, both to reduce the total number of regions to a manageable level and to adjust the sizes of the regions to realistic values (fig. 6). This is the point where the greatest amount of subjectivity was encountered. Where it was possible, this adjustment was based on topography. Rarely, a station categorized as being in a particular climatic zone was shifted to an adjoining one. Unless the presence of two or more data points made it obviously incorrect, divisions between areas were alined parallel to mountain ranges and perpendicular to the direction of river valleys. This feature is particularly evident in the treatment of the areas which appear in figure 4, along the coastal ranges of the northern Gulf of Alaska and along the arc of the Alaska Range, and which are consolidated into fewer areas in figure 6.

The presence of numerous data points which define separate climatic regimes within the Knik, Matanuska, and Susitna River valleys south of the Alaska Range is also apparent from a comparison of figure 4 with figure 6. Within the range of the subclassifications derived by use of the mean and the standard deviation of the station values, the climate of the Palmer area differs from that around Anchorage, and both are different from that around Talkeetna, and so on.

The 44 original regions were eventually reduced to 25. This number, however, includes areas which could not, by any stretch of the imagination, be considered sensitive to wildfire such as the mountainous areas on the north coast of the Gulf of Alaska and the high sections of the Alaska Range. When these areas are removed from consideration, 20 separate climatic subclassifications still remain.

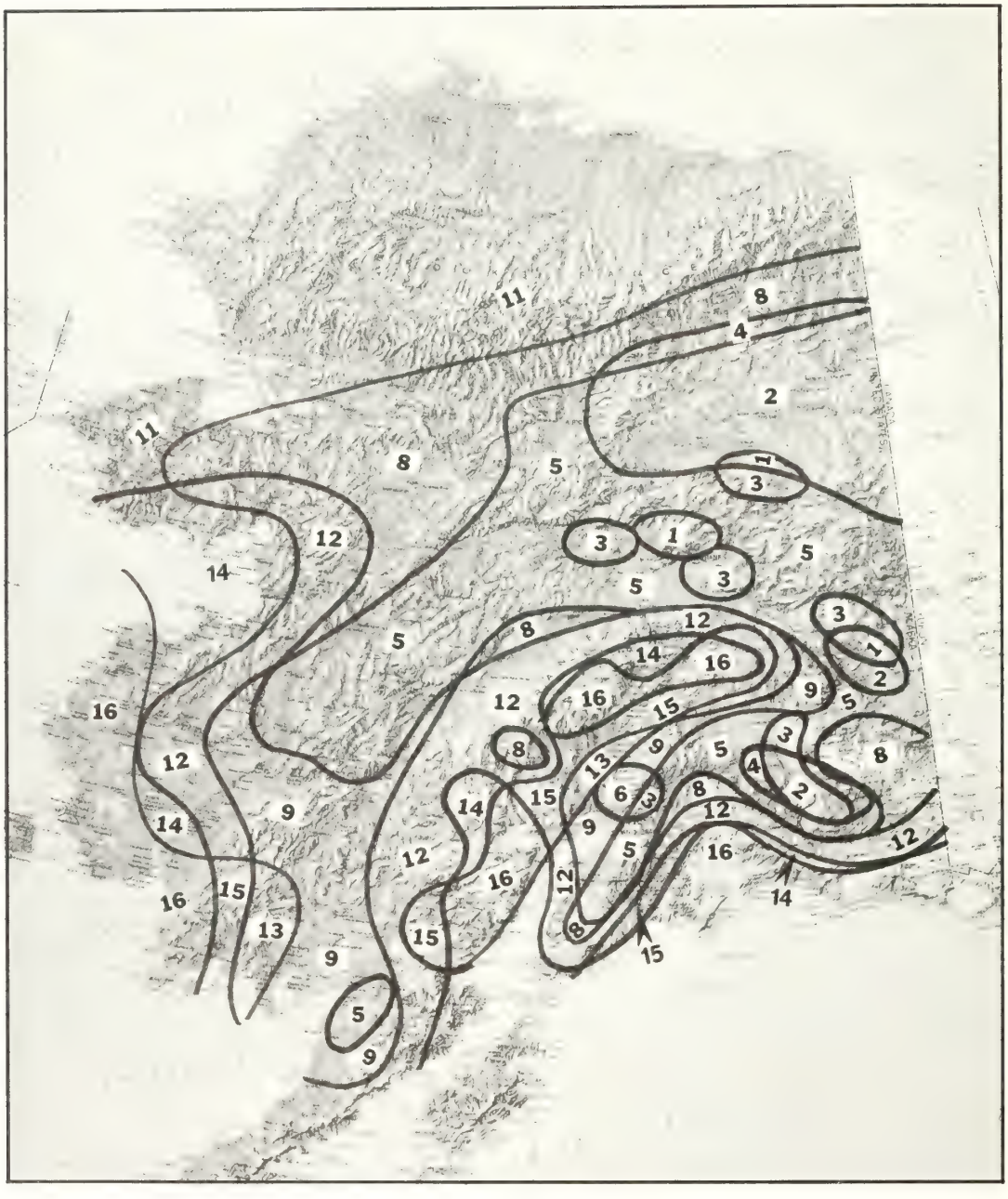

Figure 4.—Map showing composite PEI-TEI climatic zones produced when map in figure 2 is overlaid on that of figure 3.

Figure 5.—Names and identifying numbers for composite PEI-TEI climatic zones.

TEI CLASS	PEI CLASS			
	ARID	DRY	MOIST	WET
HOT	Hot-arid 1	Hot-dry 3	Hot-moist 6	Hot-wet 10
WARM	Warm-arid 2	Warm-dry 5	Warm-moist 9	Warm-wet 13
COOL	Cool-arid 4	Cool-dry 8	Cool-moist 12	Cool-wet 15
COLD	Cold-arid 7	Cold-dry 11	Cold-moist 14	Cold-wet 16

DISCUSSION

This scheme of climatic subclassification is expected to provide fire control supervisors and fire weather forecasters with a first approximation of the size and shape of the areas for which particular weather stations' observations may be generalized and considered representative. In addition, the technique described of integrating temperature and precipitation values allows a comprehensive, graphic description of integrated parameters in the form of climatic zones. This same technique can be used to derive climatic zones based on longer or shorter periods of time. The zones as outlined in this paper, derived over the 6-month fire season, have value as a wildfire management planning tool.

This paper basically designates the maximum and minimum fire danger areas on a seasonal basis. It further points out where inadequate data exist as well as extreme or peculiar climatic variations of particular areas. Further work of a more detailed nature is probably desirable, but this depends on the needs and capabilities of both fire weather and fire control personnel.

Figure 6.—Map showing composite PEI-TEI climatic zones produced when map in figure 2 is overlaid on that of figure 3—after consolidation.

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1971
USDA FOREST SERVICE RESEARCH PAPER PNW - 127

GROWTH AND SOIL MOISTURE IN THINNED LODGEPOLE PINE

Walter G. Dahms

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE
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ABSTRACT

A lodgepole pine levels-of-growing-stock study showed that trees growing at lower stand densities had longer crowns and grew more rap-

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Keywords: *Soil moisture, stand density, lodgepole pine, forest measurement.*

ACKNOWLEDGMENT

I would like to acknowledge the assistance of Dr. C. T. Youngberg, Oregon State University Soils Department, for suggesting the soil moisture aspects of this study and for furnishing the Nuclear Chicago probe to take the soil moisture measurements.

INTRODUCTION

Reward from thinning lodgepole pine (*Pinus contorta* Dougl.) may be greater than that from thinning most other species. Only a small portion of the wood produced in natural stands is on merchantable trees, and in many especially dense stands only an occasional merchantable tree is grown. The unusable trees die or are knocked down at the time of logging to become a residue problem (fig. 1).

Figure 1.–A major portion of the total wood produced by dense natural lodgepole pine stands ends up as unused residues that are costly to dispose of.

Results of the levels-of-growing-stock study reported in this paper indicate that foresters can capture most of the total wood production on usable-sized trees by controlling stand density. Furthermore, the low density that looked best for timber production up to the present stand age also withdrew less water from the soil.

STUDY AREA

The Twin Lakes levels-of-growing-stock study is located on the Deschutes National Forest near Twin Lakes and Wickiup Reservoir. It is about 10 miles west of the Pringle Falls Experimental Forest and about 45 miles southwest of Bend at an elevation of approximately 4,300 feet.

Topography of the study area is very gently sloping toward a bowl-shaped depression with one end open. There is good water drainage.

The present young stand that originated following a fire in 1934 is primarily lodgepole pine in the lower areas. Ponderosa pine (*Pinus ponderosa* Laws.) tends to increase with only a very slight rise above the depression floor, and a rise of only a few feet completes the transition from lodgepole to ponderosa pine in most places. However, stumps of mature ponderosa pine are numerous throughout the area presently occupied by lodgepole pine, indicating that the site is capable of supporting either.

Cold air drainage into the lower portions of the area probably accounts for presence of lodgepole pine there rather than ponderosa pine. Berntsen (1967) demonstrated that, of the two pines, lodgepole is considerably more tolerant of freezing temperatures during the first spring after germination. He concluded that this greater frost tolerance of lodgepole pine accounts for its presence in many low-lying cold flats in central Oregon. Filtering in of ponderosa pine seedlings under an existing lodgepole pine canopy in a manner described by Cochran et al. (1967) could easily account for the old-growth ponderosa pines that existed in the lodgepole pine portions of the present study area. An unusually frost-free spring could also have permitted ponderosa pine establishment.

Understory vegetation makeup varies with position on the slope even though elevation changes amount to only a few feet. In the lower areas occupied predominantly by lodgepole pine, predominant plants are bitterbrush (*Purshia tridentata*), squaw currant (*Ribes cereum*), strawberry (*Fragaria cuneifolia*), needlegrass (*Stipa occidentalis*), and Ross sedge (*Carex rossii*). Occasionally dogbane (*Apocynum androsaemifolium*) and princespine (*Chimaphila umbellata*) were also found. Snowbrush (*Ceanothus velutinus*) is sparsely represented. However, where even a slight slope was encountered, snowbrush tended to become the dominant understory shrub. Thus vegetation on the lower portion closely resembled the lodgepole pine/bitterbrush-currant community of Youngberg and Dahms (1970) and that on the more sloping portions, the *Pinus ponderosa/Ceanothus velutinus-Purshia tridentata* community of Dyrness and Youngberg (1966).

Soil belongs to the Lapine series.[1/] It was developed from dacite pumice deposited during the eruption of Mount Mazama approximately 6,500 years ago. Total pumice depth ranged from 25 to 51 inches and averaged 37 inches at the 37 locations sampled. Plot-to-plot variation

[1] *Personal communication with Patrick H. Cochran, soil scientist, Pacific Northwest Forest and Range Experiment Station, Bend, Oregon.*

was surprisingly small and could easily be accounted for on the basis of variation among sampling points within plots.[2]

The pumice overlays an older, predominantly sandy loam soil. The older soil profile averages 15 inches in depth to a compacted layer similar in texture to the soil above it. This layer defines the lower limit of rooting depth (fig. 2). Total depth of soil, both pumice and buried sandy loam, ranged from 42 to 62 inches and averaged 52 inches at the 12 locations sampled.

Site index for the study area as a whole averages 72 feet at age 50 years for the tallest lodgepole pine tree per one-fifth-acre plot (read from Dahms (1964) site index curves[3]). Actual tallest tree height at age 35 years averaged 52.5 feet, ranging from 49.5 to 56.2 feet.[4] These heights are considerably above averages for central Oregon lodgepole pine at 35 years.

Figure 2.—Roots of this windthrown ponderosa pine tree abruptly stopped their downward penetration when they encountered the compacted soil layer. This tree had been growing immediately adjacent to the lodgepole pine thinning area, on similar soil.

[2] *Most of the sampling points consisted of auger holes drilled to accommodate access tubes for measuring soil moisture with the neutron probe. Pumice depth measurements were taken in the holes used for each of the first three tubes installed on each of the original 10 plots. Other depth-of-pumice measurements came from a large soil pit and from several smaller ones dug in 1970.*

[3] *Site index 72 is substantially higher than that reported by Dahms (1967) because an average of three tallest trees per plot was used to estimate 1959 site index. This was done to strengthen comparisons between plots in a very young stand. Had the single tallest tree per plot approach been followed in 1959, the answer would have been site index 70. Use of the single tallest tree per one-fifth acre is the only valid way to estimate site index for use with the gross yield table.*

[4] *Age 35 years was used because the tallest trees probably originated the first year after the 1934 fire even though stand age averages only 32 years. Site index is extremely sensitive to small errors in age in young stands.*

THE EXPERIMENT

The experiment is a levels-of-growing-stock study designed for thinning at frequent intervals. Three thinnings have been made to date, the initial one in 1959, followed by rethinnings in 1964 and 1969. Rethinnings were at the same 5-year interval used for measuring growth and were done in the fall after all trees had been remeasured.

Growing-stock levels initially chosen for testing were 7,500; 12,500; 17,500; 22,500; and 27,500 square feet of bole area per acre.[5/] Density on plots selected for the two highest levels was not high enough to meet specifications in 1959. After the 1964 remeasurement, 4,000; 8,000; 12,000; 16,000; and 20,000 square feet of bole area were selected as the new density definitions. The change was made because 20,000 square feet seemed enough to fully occupy the site at one end and because density had not been reduced enough at the low end to clearly reduce cubic-volume increment.

The 1969 thinning was made to the same bole area specifications as the 1964 thinning. Basal areas corresponding to the densities of 4,000, 8000, 12,000, 16,000, and 20,000 square feet of bole area per acre in 1964 were 26.8, 45.3, 63.8, 78.8, and 95.0 square feet per acre, respectively (table 1). Well-stocked portions of the unthinned stand in 1964 contained 125 to 130 square feet of basal area per acre. Figures 3, 4, and 5 provide further help in visualizing the treatments applied.

Excess trees cut to achieve the desired densities were mainly the diseased and small individuals. However, at the two lower densities, some excellent trees were cut to reach the desired level. At the two higher densities, not all diseased or low vigor trees could be eliminated. Spacing was also a factor in choosing trees to be cut.

Limbs were lopped from the fallen trees, and many stems were cut into several lengths. Consequently, slash exerted only a minor understory suppressing effect (figs. 3, 4, and 5).

The experiment is a completely randomized design with two plots randomly assigned to each of the five levels of growing stock. Originally plots were 0.1 acre in size, the largest reasonably homogeneous plot areas that could be found if the highest density treatment were to be applied. At the time of the 1964 thinning when density definitions for all treatments were lowered, it became apparent that not enough trees would be left on 0.1-acre plots at the lower densities. Consequently, size of plots at the lowest density was increased to 0.4 acre and at the next higher density to 0.2 acre. Most of the area added

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[5] *Bole area is a close estimate of the cambium area of the tree stem. Lexen (1943) more fully describes bole area as a measure of stand density.*

Table 1.--*Stand statistics per acre after the 1959 thinning and before and after the 1964 and 1969 thinnings.*

Growing-stock level	Number of stems	Spacing[3]	D.b.h.[3]	Height[3]	Basal area	Bole area	Crown competition factor	Total volume[4]
		Feet	*Inches*	*Fee*	*--Square feet---*			*Cubic feet*
After the 1959 thinning:								
1 (lowest)	405	10.4	4.2	26.0	41.7	7,330	64	542
2	610	8.4	4.4	28.2	70.0	12,454	102	978
3	925	6.9	4.0	27.2	85.3	16,538	136	1,168
4	1,345	5.7	3.4	24.6	92.4	19,305	164	1,209
5 (highest)	1,705	5.1	3.0	22.8	93.6	20,248	182	1,173
Before 1964 thinning:								
1	405	10.4	5.2	32.4	62.0	10,496	84	1,016
2	610	8.4	5.0	34.1	88.6	16,343	121	1,461
3	920	6.9	4.5	33.2	107.4	21,822	158	1,806
4	1,315	5.8	3.8	30.3	113.6	24,700	184	1,765
5	1,645	5.1	3.4	27.9	115.4	25,078	201	1,725
After 1964 thinning and plot enlargement--individual plot equations:[1]								
1	114	19.5	6.5	37.3	26.8	4,264	32	460
2	260	12.9	5.6	35.8	45.3	8,050	59	744
3	400	10.4	5.3	36.5	63.8	12,352	86	1,092
4	675	8.0	4.5	33.5	78.8	16,131	116	1,253
5	1,065	6.4	4.0	30.4	95.0	20,255	151	1,403
Spacing[2]	85	22.6	7.9	41.7	29.6	3,982	32	566
Before 1969 thinning--after additional climbed trees added:								
1	114	19.5	7.7	43.8	37.8	5,976	42	729
2	258	13.0	6.4	42.4	58.6	10,963	71	1,170
3	400	10.4	5.9	42.2	78.3	16,214	99	1,588
4	670	8.1	5.0	38.8	93.4	20,970	130	1,790
5	1,050	6.4	4.3	35.4	108.5	25,966	166	1,974
Spacing[2]	85	22.6	9.1	46.4	38.8	5,491	39	766
After 1969 thinning and plot additions:								
1	71	24.8	7.9	44.4	25.1	3,917	27	496
2	170	16.0	6.8	42.9	43.4	8,059	51	867
3	265	12.8	6.4	43.8	60.1	11,991	73	1,252
4	478	9.5	5.2	39.7	72.3	16,015	98	1,417
5	750	7.6	4.4	35.8	84.7	19,936	126	1,578
Spacing[2]	85	22.6	9.1	46.4	38.8	5,491	39	766

[1] Volume and bole area figures differ from those previously published because individual formulas were substituted. Other figures differ because of plot enlargements. However, published number of trees for 1964 after thinning was found to be slightly in error on treatments 3 and 5.

[2] Two plots added in 1963 in relatively open portions of the stand.

[3] Arithmetic average.

[4] Total peeled volume including tips and stumps.

Figure 3.–A plot of the highest density immediately after the 1959 thinning, which left 1,705 trees per acre. Only a few of the very poorest trees were cut.

Figure 4.–A plot of the lowest density immediately after the 1959 thinning. This treatment left an average of 405 trees per acre.

Figure 5.–A low density plot after the 1969 thinning. Note how slash from earlier thinnings has been flattened to the ground by snow. The only visible understory vegetation here is a few scattered bitterbrush plants.

came from the 1/2-chain buffer strip surrounding each plot. Size of the remaining six plots was increased to 0.2 acre at the time of the 1969 thinning. Small holes that had seemed too large in the 22-year-old stand in 1959 were mostly occupied by the larger 32-year-old trees in 1969 and therefore acceptable for inclusion within a plot.

Random assignment of treatments to plots after all had been chosen meant that all plots had to come from the denser portions of the original stand to be satisfactory for the highest density treatment. Consequently, there were no low density plots in portions of the stand that had started out at a low density. To remedy this situation, two additional 0.2-acre low density plots were installed in 1963. These plots were put in portions of the stand that had grown up under open conditions with good individual tree development. These plots were thinned again in 1964 to meet the new treatment definitions but no further thinnings are planned. Consequently, they are designated spacing plots. Because these plots were not a part of the original random selection, they cannot be included in most tests of significance between treatments. However, it is legitimate to make comparisons to the extent that we believe differences at the time of plot installation really stem from accidents of seedling establishment rather than real growing site differences.

MEASUREMENTS

Measurements of trees and soil moisture were made during the 10-year period from the fall of 1959 through the fall of 1969. Crown density of understory vegetation was measured during the 1970 growing season.

Tree measurements of the following kinds were made:

1. Diameter, height, and height-to-live-crown were measured on each tree in 1959, 1964, and 1969. Diameters were measured with a tape to the nearest 0.1 inch. Heights and height-to-live-crowns were measured with a sectioned pole and recorded to the nearest 0.1 foot.

2. Detailed measurements were made on a sample of trees to provide the basis for calculation of volume and bole area of each of these individuals. For this purpose caliper measurements outside bark were made at 1.0-, 4.5-, 10.0-, 20.0-, and such additional even 10-foot distances up the tree as could be reached by climbing. Initially bark thickness was measured at each calipered point. Later it was measured only at 1.0 foot above the ground and at breast height (b.h.). At higher points it was calculated on the assumption that bark constituted the same percentage of diameter outside bark as it did at breast height.

Five trees per plot, chosen on the basis of diameter, constituted the detailed measurement sample in 1959. These same trees were remeasured in 1964 before thinning. After thinning, enough additional trees were measured to bring the total number of standing climbed trees to 10 per plot. Because some of the original five climbed trees were were removed by thinning, it was necessary to add more than five trees on most plots to bring the total to 10. In 1969 the same 10 climbed trees left from 1964 were completely remeasured before thinning and enough trees added after thinning to again bring the total of standing climbed trees to 10 per plot.

3. Diameters of crowns were measured on a sample of trees. All trees at the lowest densities were measured, but at higher densities only every second, third, or fifth tree was measured, depending on the number of trees in the plot. A total of 305 crown widths were measured on all 12 plots. Diameters were measured in two directions as nearly at right angles to each other as could be determined by eye. Measurements were made with the aid of a plumb bob rigged on a pole. Tip of the pole was held at the outside of the crown and the plumb bob dropped to the ground. Actual crown diameters were measured between plumb bob points on the ground. These measurements were made only in the fall of 1969.

4. Diameters were measured to the nearest 0.01 inch with a tape to determine seasonal progress of diameter growth on the same sample trees used for crown width measurements during the 1969 growing season.

Soil moisture was measured with a neutron probe beginning in 1961. At first, frequent measurements were made during the growing season beginning immediately after snowmelt. Later, as it became apparent that the soil was fully charged each spring and that the seasonal pattern of withdrawal was similar, measurements were made only at the end of the growing season.

Four mechanically located access tubes, each 5 feet long, were used as sampling points on each plot. Readings for each tube were taken at 1-foot intervals beginning 1 foot below the soil surface. Probe readings were converted to percent moisture by volume using a calibration curve developed by Barrett (1970).

Understory vegetation crown cover was estimated in 1970 by systematically sampling each plot with approximately 100 points using methods described by Heady et al. (1959). Snowbrush, other shrubs, grasses and sedges, and herbs were the classes of vegetation recognized. No vegetation measurements were taken prior to 1970.

CALCULATIONS

Volume of individual trees was calculated using Smalian's formula for the main part of the bole. Volume of the 1-foot stump was calculated as a cylinder, and volume of the tip was obtained on the assumption that the cross-sectioned area at the half-length point would be half that at the base.

Bole area of individual trees was obtained by calculating surface area of the same sections used for volume calculations and summing them to total bole area for the tree. Each section was treated as a cylinder, with circumference obtained from the circle of average cross-sectional area. Bole area as calculated under bark was approximately equal to cambium area of the main stem.

All diameter values used for calculating volume and bole area of individual trees were based on caliper measurements. This included measurements at b.h.

Initially, volume and bole area of each completely measured tree were calculated inside bark. However, inspection of the data revealed that measurements made in 1964 showed consistently thicker bark than in either 1959 or 1969. Measurements made in 1959 and 1969 were very similar. Therefore, volumes were all calculated outside bark. Inside bark volume from the 1959 and 1969 measurements combined averaged 87.18 percent of outside bark volume. A comparison of regressions of volume D^2H for inside and outside bark showed there were no consistent trends of different percentages with tree size within the range of tree sizes encountered. Therefore, inside bark volume for all three dates was obtained by first calculating outside bark volume and then multiplying by 0.8718.

An attempt was made to similarly adjust bole area for bark measurement discrepancies. However, trends associated with tree size complicated the process to the point that unadjusted values were used.

Volume and bole area for the climbed trees were expressed as functions of diameter and height. Diameter breast high determined by diameter tape was used for this purpose to be consistent with the diameter tape measurements made on the unclimbed trees to which the equations were to be applied. One volume and one bole area equation were developed for all climbed trees on all plots in 1959 and the same trees in 1964. Volume and volume increment figures contained in Dahms (1967) were based on these equations.

Individual volume and bole area equations were developed for each plot after the additional climbed trees were added. Because the individual plot regressions for volume and bole area did not differ greatly

from the single experiment-wide ones, the individual ones were used as the basis for computing both the ending volumes and bole areas for the 1960-64 period and the beginning values for the 1965-69 period.

Volume and bole area equations for each plot in 1969 were based on all climbed trees available, including those added as replacements for the ones cut in the 1969 thinning. These equations were also used to calculate volume and bole area figures that served as ending values for the 1965-69 period and beginning values for the 1970-74 period.

The switch to individual plot volume and bole area equations, with the attendant requirement of many more climbed trees and the much greater calculation load, was made possible by computer calculations. Hand calculator computations had been envisioned when this study was in the design stage.

RESULTS

Crown

Crowns were both wider and longer at the lower stand densities in 1969 (fig. 6). These conclusions were reached from the 100 trees of largest diameter per acre. Consequently, the large number of small trees present only at the higher densities did not affect conclusions.

Crowns of the 100 largest trees were increasing in length at all densities. That is, trees were growing more rapidly in height than the lower part of the crown was receding through branch death. However, rate of increase was significantly greater at the lower densities.

Height growth of the largest trees averaged 13.4 feet during the 10-year period from 1959 through 1969 and was not significantly affected by stand density. Minor differences from one treatment to another could easily be accounted for by variations between plots treated alike.

Rate of crown recession from death to lower branches was definitely faster at the higher densities. Following is the average number of feet of crown lost over the 10-year period from 1959 through 1969 by density level:

Density level	*Crown recession* (feet)
1 (lowest)	2.35
2	4.30
3	5.35
4	5.65
5 (highest)	7.05

Differences in amount of crown lost between density levels are highly significant in a statistical sense.

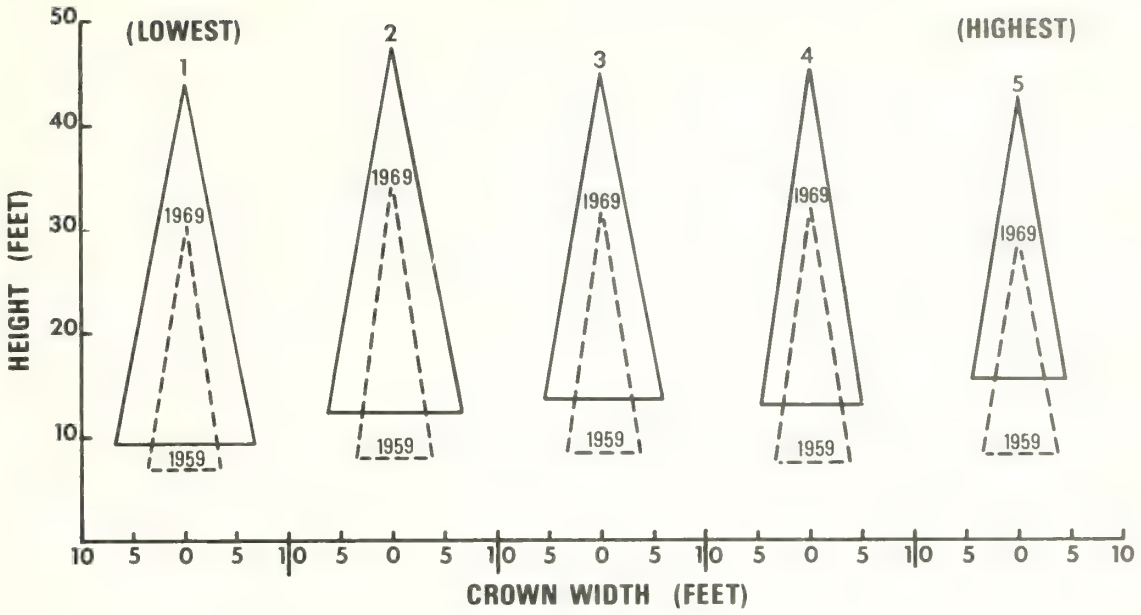

Figure 6.–Crown size of 100 largest trees per acre in 1959 and 1969 by density treatment. Crown widths for 1959 were estimated from 1969 regressions of crown width on diameter, 1959 crowns are shown as dotted lines.

Crown width increased steadily as tree diameter increased across the entire range of diameters. Regressions of crown width on stem diameter breast high within each of the density levels were all highly significant in a statistical sense. However, differences in slope of regressions between density levels were small and did not approach statistical significance.

Crowns also tended to be wider at comparable diameters for trees growing at the lower densities. Following is a comparison of crown widths among density levels before and after adjustment for diameter differences:

Growing-stock level	*Average diameter* (Inches)	*Average crown width* (Feet)	*Adjusted crown width* [6] (Feet)
Spacing [7] (lowest)	9.1	15.2	11.0
1	7.7	13.4	11.2
2	6.5	11.0	10.7
3	5.9	9.6	10.2
4	4.9	7.4	9.5
5 (highest)	4.1	6.3	9.5

[6] *Crown width adjusted to a tree diameter of 6.3 inches, the average diameter of the 305 trees on which crown width was measured.*

[7] *The spacing plots were the ones selected later in the less dense portions of the original stand. They could not be included in figure 6 because no 1959 information was available.*

A covariance analysis showed there were statistically significant differences in crown widths between density levels after adjustment to one average diameter. Evidently crown widths on trees of all sizes have been increasing relatively more rapidly than stem diameter at the low stand densities than at the high densities. Because of the longer crowns, branches on trees growing at lower densities have more years to grow. There is also a distinct possibility that branches on trees with more growing space may also grow more rapidly.

Diameter

Diameter growth was most rapid at the lowest level of growing stock and slowest at the highest levels during both periods (fig. 7). These differences in diameter growth rate between growing stock levels were statistically highly significant.

There was some tendency for diameter growth of all trees as a group to slow from the first period to the second at equivalent densities. There were also some diameter growth increases in response to additional growing space. For example, at the lowest density where the 1959 thinning left 7,300 square feet of bole area per acre but the 1964 thinning reduced it to 4,300 square feet, diameter growth increased from an annual rate of 0.20 inch to 0.24.

Diameter increase of the 100 largest trees per acre was slightly more rapid than diameter growth of all trees during both periods (figs. 7 and 8). The general trend of increasing diameter growth with decreasing stand density held for largest trees in about the same way as for all trees. Differences between levels were statistically significant during both growing periods.

Diameter growth was only weakly related to initial diameter at the higher densities, and almost no relationship existed at the lower end of the density scale. A regression of diameter growth on diameter at the beginning of the period was statistically significant on each of the four plots at the two higher density levels and on one plot at the lowest density level. However, similar regressions were not significant on seven other plots, all at the low and medium density levels. The relationship between diameter and diameter growth in this young lodgepole stand was too weak and uncertain to be of any practical value.

Diameter growth during the second period was closely related to diameter growth during the first. Regressions of second period diameter growth on first period growth for individual plots were all highly significant. They accounted for from 39 to 69 percent of the total variation. Thus past performance as indicated by growth during the first period was a good guide to future performance. However, past performance as indicated by beginning diameter in the 27-year-old

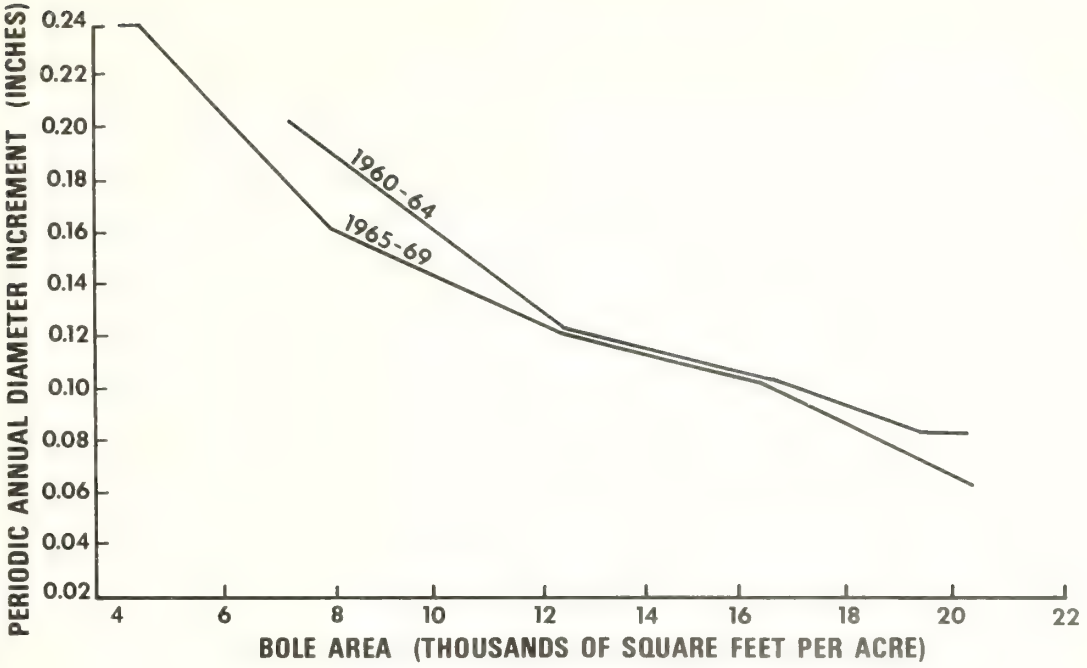

Figure 7.–Periodic annual diameter increment by period and stand density.

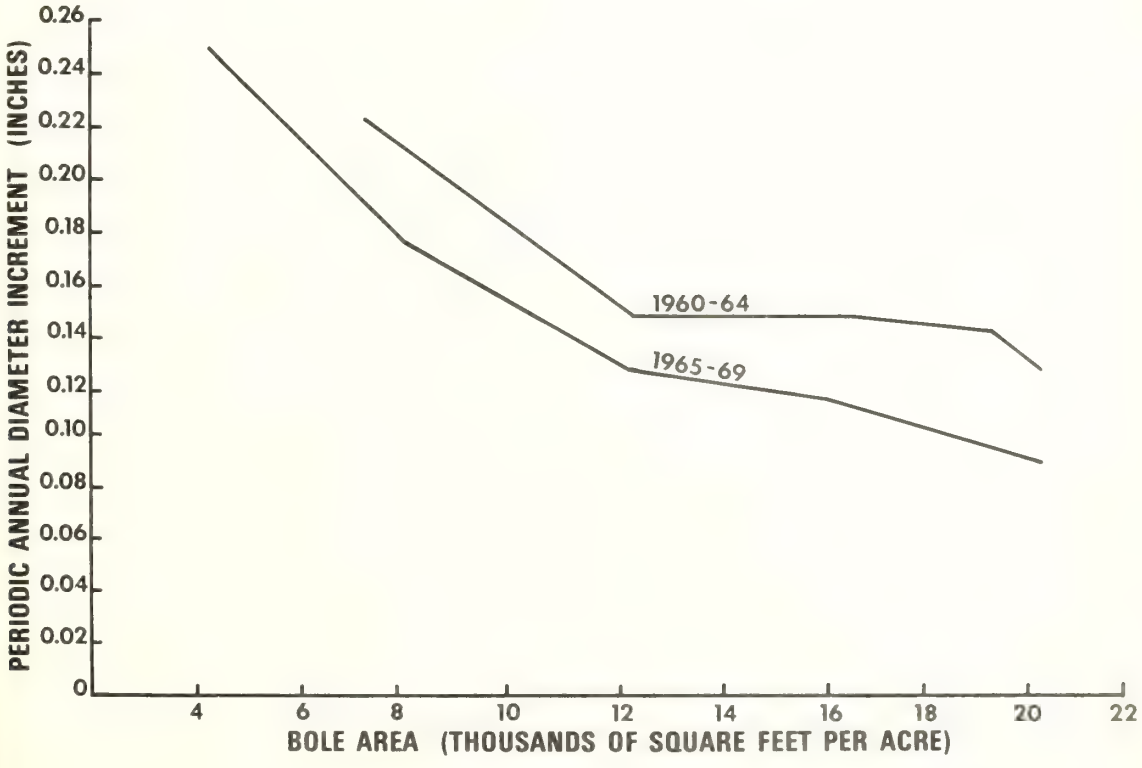

Figure 8.–Periodic annual diameter increment of 100 largest trees per acre by period and stand density.

Twin Lakes stand was not a good estimator of future performance. Although diameter is almost certainly a good integrator of average growing conditions during the life of a tree, it is not necessarily a good indicator of current growing conditions. This may be especially true when the competitive status of individual trees is modified by thinning.

Diameter growth was more strongly related to crown size than to initial diameter, but even this better relationship was not strong enough to be really useful.[8] Crown width, crown length, and width x length were the three criteria of crown size used as diameter growth predictors in regression equations. All of these equations, one for each of the six thinning treatments, proved to be significant in a statistical sense. However, percent of total variation accounted for by regression was low. It ranged from 9.5 to 32.4 percent of total variation in diameter growth. Furthermore, none of the three independent variables proved clearly superior to the others. Each proved best in two of the six equations. Thus the prospect of predicting growth rates of lodgepole pine from crown size is not encouraging.

The combination of increased growth of trees on the low density plots and increased average diameter resulting from removal of smaller trees has raised average diameter of trees at the lowest density level 3.5 inches above that at the highest level (table 1). Most of the difference, 3.2 inches, has developed during the past 10 years. Faster growth at the lowest density accounts for 1.5 inches, or about half of the total.

Diameter growth was most rapid during late spring and early summer (fig. 9). Substantial growth did not begin until after May 22 on the one plot where earlier measurements were made. As the summer advanced, growth gradually slowed; and by late August or early September, it had nearly stopped.

There was no general tendency for growth to stop sooner on high density than on low density plots. However, there were unexplained aberrations, principally on the high density plots, that cannot be dismissed as measurement inaccuracies on a few trees because the trends were common to most trees. An example is the shrinkage of trees in the 12,000- and 20,000-foot plots in late August and early September.

Height

Height growth of all trees ranged from a high of 7.7 feet on one plot to a low of 4.1 feet on another and averaged 5.8 feet during 1965-69. There was some tendency for greater growth at the lower

[8] *The analyses relating diameter growth to crown size and to diameter at the beginning of the period were both done with data from the 1965-69 period only. Crown width was measured only in 1969.*

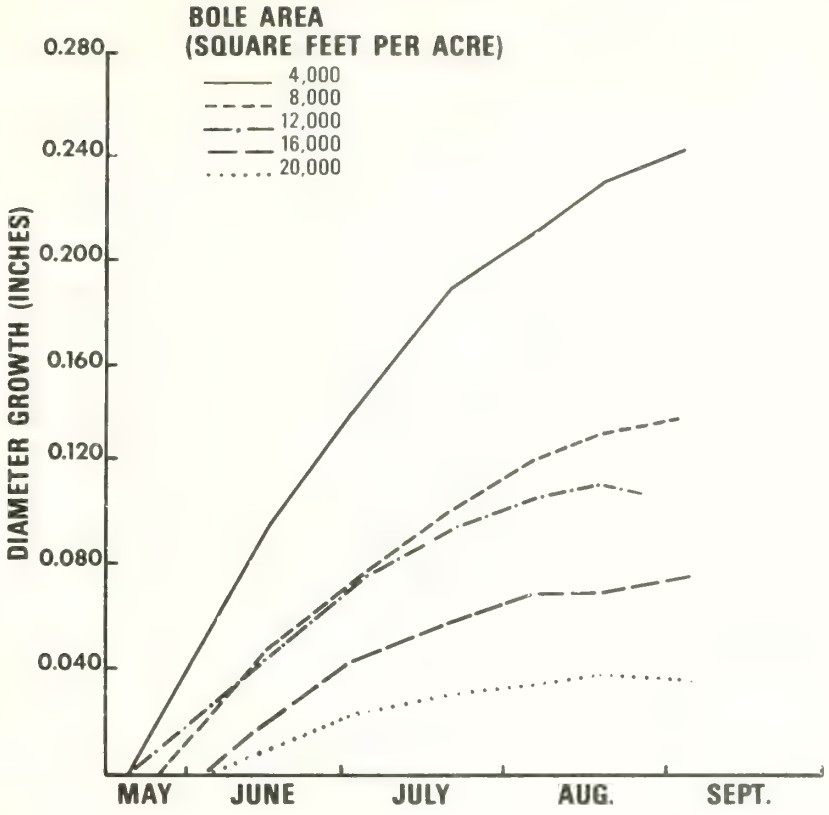

Figure 9.—Seasonal progress of diameter growth during 1969 by stand density.

densities; however, it could easily be accounted for by variation among plots treated alike. Height growth during the second 5-year period was very similar to that during the first.

Height increase of the 100 largest trees per acre was only slightly better than that for all trees. Height increase of these larger trees averaged 6.4 feet and ranged from an average of 5.4 feet on one plot to 8.0 on another.

Basal Area

Basal area increment averaged 4.2 square feet per acre annually during 1960-64 but fell to 2.7 square feet during 1965-69.[9] The drop represents mainly the normal decrease with increasing age, but lower densities at most levels during the second period were almost certainly partly responsible (fig. 10).

[9] *These figures are for the original 10 plots only during both periods.*

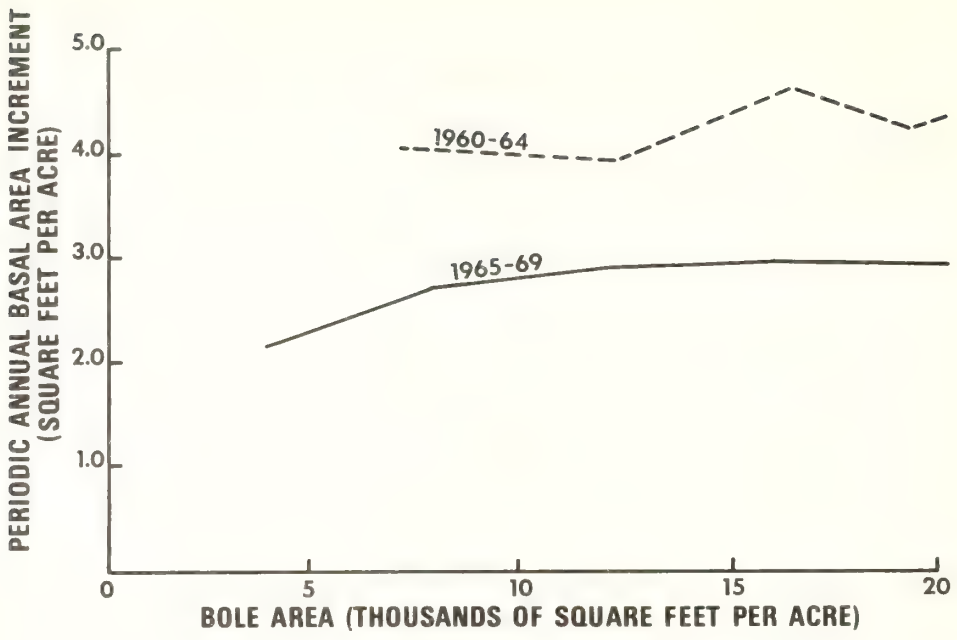

Figure 10.–Periodic annual basal area increment by period and stand density.

There was a highly significant trend of increasing basal area increment with increasing basal area during the second period (fig. 11). Variation among plots treated alike was too great to support a curved regression over a straight line. However, common sense strongly suggests a curve form that would pass through the origin, as zero basal area must produce zero basal area increment after trees have exceeded 4.5 feet in height.

There was almost no trend of increasing basal area increment with increasing bole area during the first period. Slope of a regression of basal area increment on bole area did not come close to being significant.

Volume Increment

Volume increment tended to decline from the first period to the second at comparable bole area levels (fig. 12). However, the trend was not completely consistent.

Volume increment also had a tendency to increase with increasing bole area during both periods (fig. 12). During the first period, the relationship was weak. A regression of volume increment on logarithm of bole area was barely significant at the 5-percent level. However,

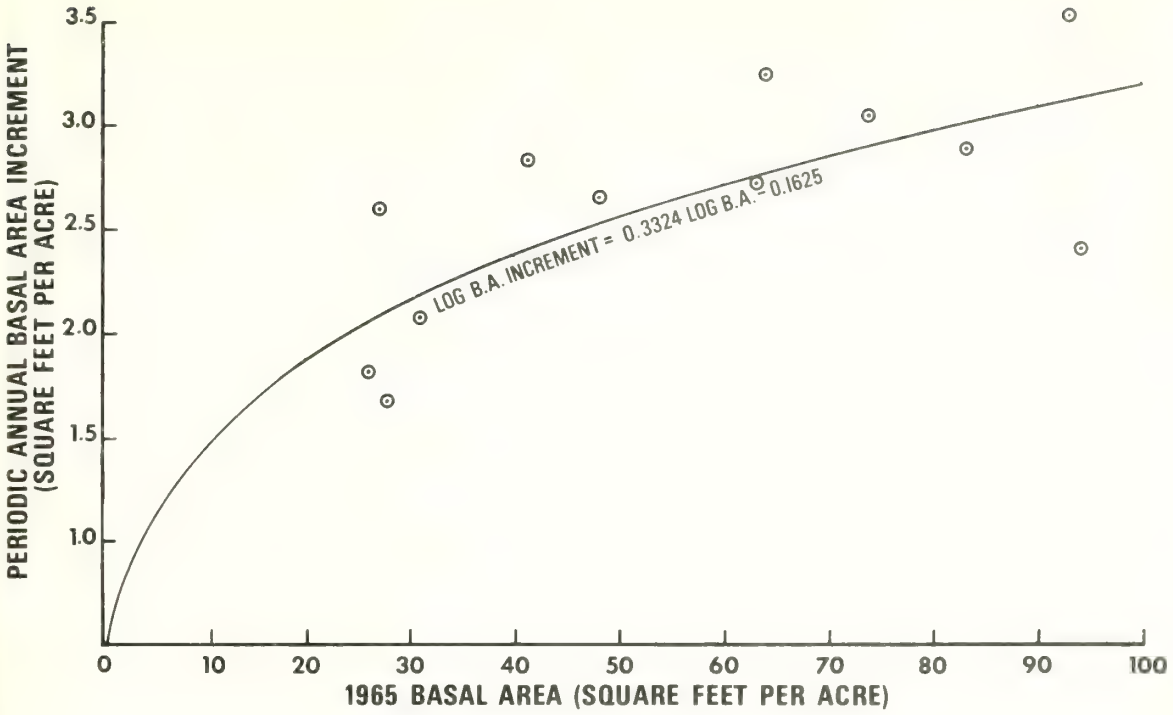

Figure 11.–Periodic annual basal area increment over initial basal area, 1965-69.

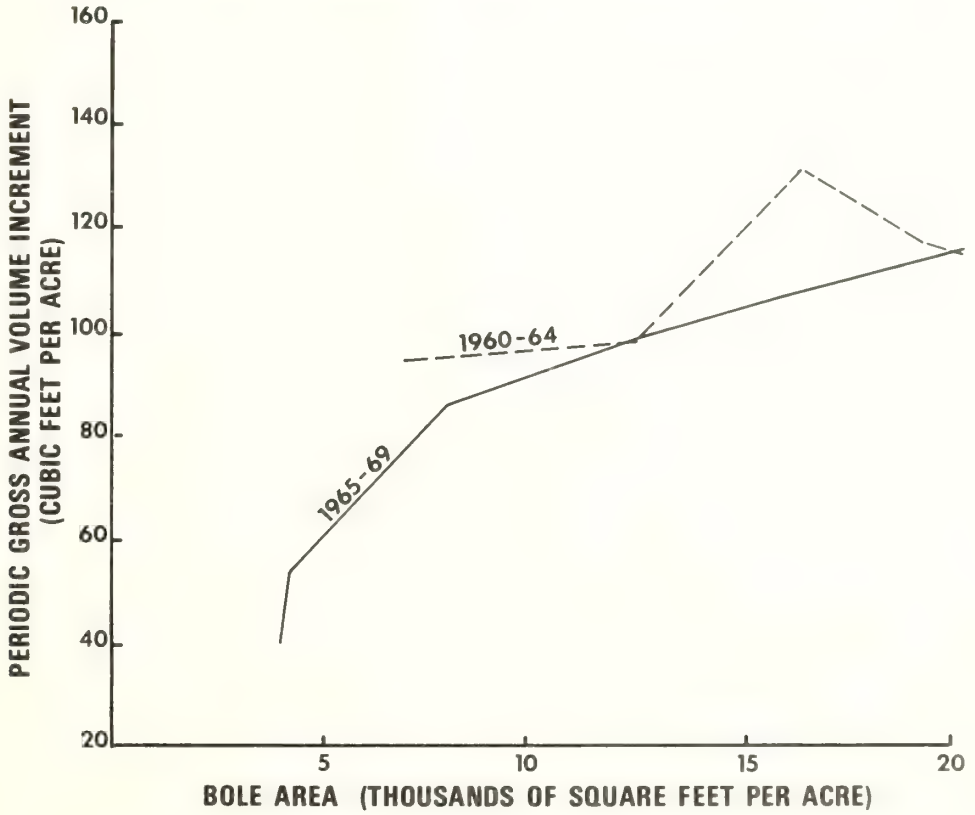

Figure 12.–Periodic annual gross cubic volume increment by period and stand density.

during the second period, a similar regression accounted for 88.0 percent of all variation and was significant far beyound the 1-percent level (fig. 13).

The stronger relationship during the second period is partly the result of a greater range of densities. The lowest level was substantially lower during the second period and therefore produced much less wood. Consequently, the range in volume increment from high to low was much greater and contrasted more strongly with the random variability among plots treated alike. There was also a tendency for plots treated alike to produce more nearly alike during the second period.

Regressions of volume increment on logarithm of basal area (fig. 14) and on logarithm of crown competition factor (CCF) (fig. 15) are very similar to the bole area regression. The bole area regression accounted for slightly more variation with the Twin Lakes data. However, the range was only from a low of 85.5 percent with the CCF regression to a high of 88.0 percent with the bole area regression.

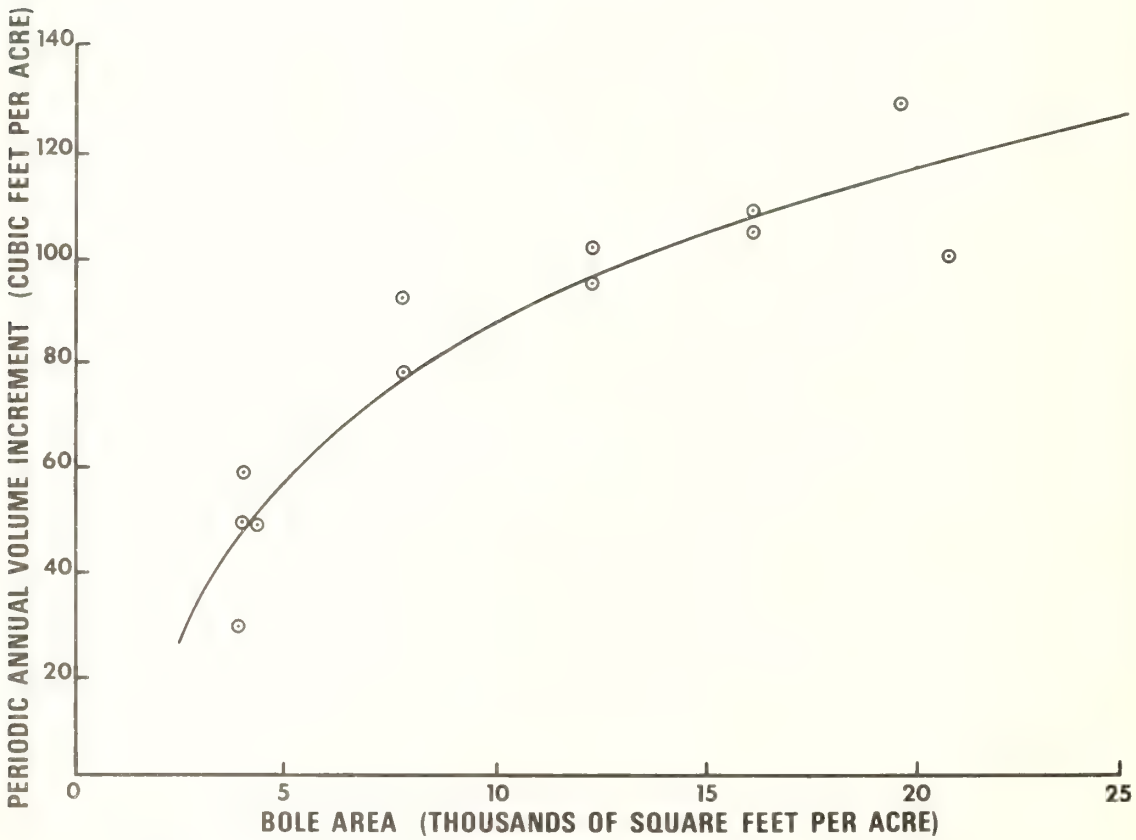

Figure 13.–Regression of periodic annual gross volume increment on log of bole area, 1965-69.

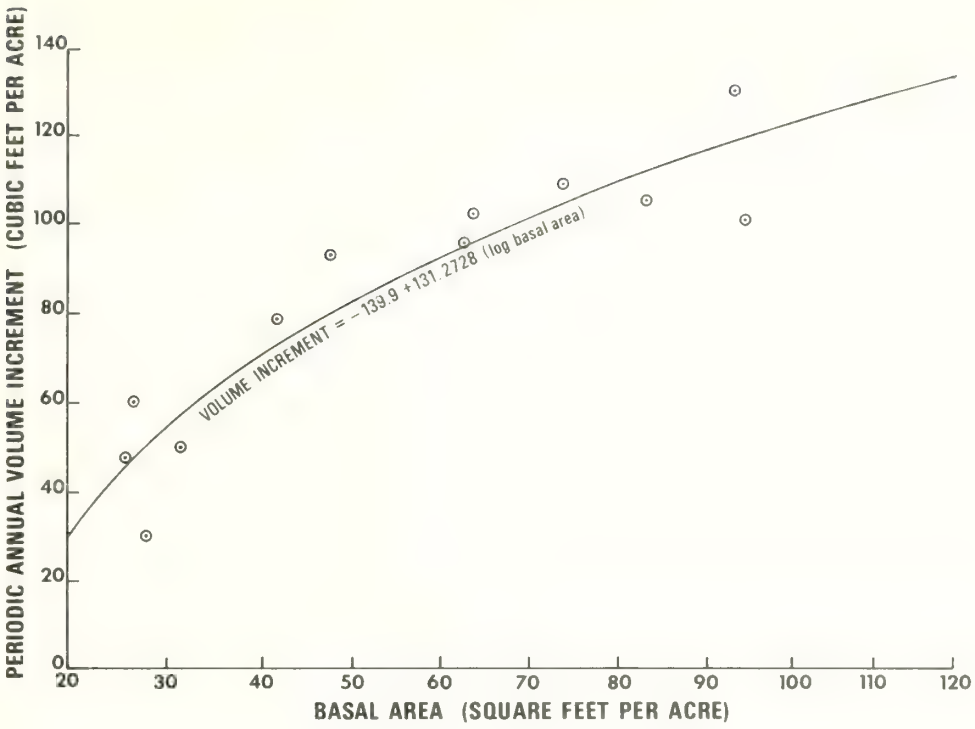

Figure 14.–Regression of periodic annual gross volume increment on log of initial basal area, 1965-69.

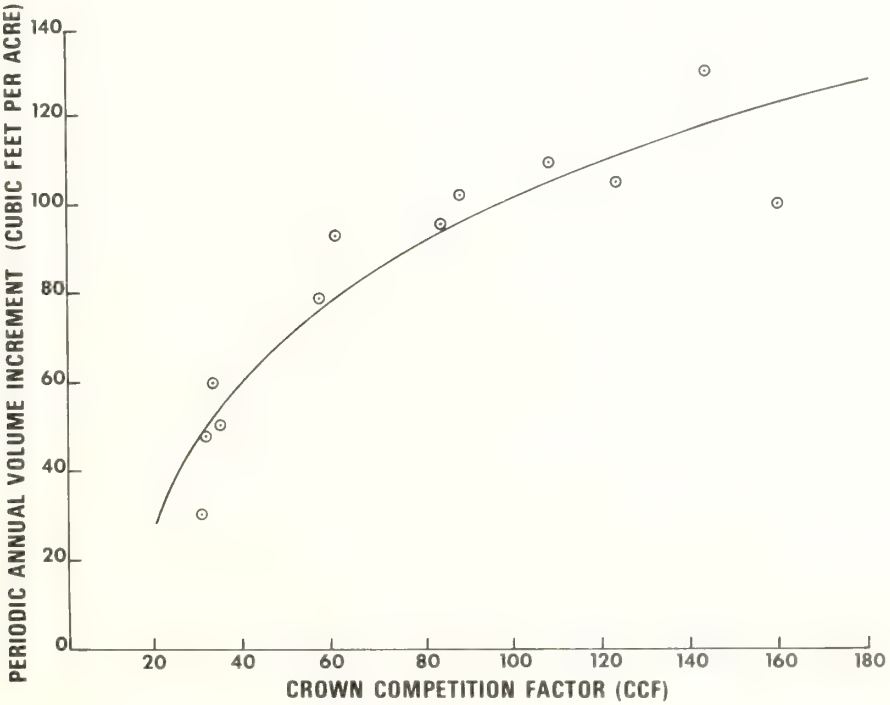

Figure 15.–Regression of periodic annual gross volume increment on log of CCF, 1965-69.

The area-occupied concept of crown competition factor can be examined in the light of actual production records. At a CCF of 33-1/3, the regression estimate of volume increment is 51.8 cubic feet per acre annually (fig. 15). Theoretically at this density trees with crowns the size of those possessed by open grown trees would form only one-third of a complete crown canopy. However, if we assume trees growing at this density are using only one-third of the site, we arrive at a full site capacity of 155.4 cubic feet per acre annually. Actual production at the higher densities (figs. 12 and 15) suggests the upper limit is somewhere in the range of 120 to 130 cubic feet per acre annually. Similarly a regression estimate of volume increment for CCF 100 is only 101.8 cubic feet per acre annually, seemingly somewhat below the full potential of the site. Thus at very low densities, lodgepole pine trees at Twin Lakes actually occupied more than the area indicated by the CCF equation; but at higher densities, they did not occupy as much area as estimated if we accept wood production as evidence of site use.

Volume increase of the 100 largest trees per acre was definitely greater during the second period than during the first. There was also a trend of more rapid increase at the lower densities than at the higher ones (fig. 16). This means that growth capacity is being transferred to the larger, more useful trees with the passage of time and that the process is taking place more rapidly at the lower densities.

Volume increment was much more sensitive to changes in stand density than was basal area increment. For example, during the first

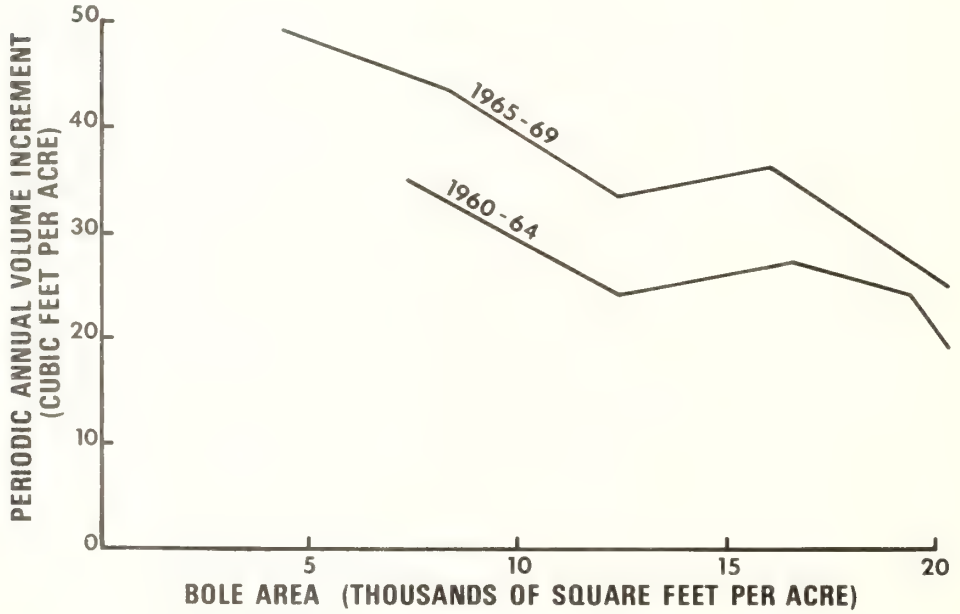

Figure 16.—Periodic annual volume increment of 100 largest trees per acre as related to stand density.

period, a regression of basal area increment on logarithm of basal area did not approach significance. However, a regression of volume increment on logarithm of bole area was significant. Similarly, during the second period, a regression of basal area increment on logarithm of basal area accounted for only 52.2 percent of all variation. But, a regression of volume increment on logarithm of bole area accounted for 88 percent of all variation. The closer relationship between stand density and volume increment suggests that more precise results can be achieved by measuring volume increment directly than by using separate estimates of basal area increment and height increment to predict volume increment.

Bole Area

Bole area was initially chosen as the measure of stand density to be used with lodgepole pine levels-of-growing-stock studies for the following two reasons.

1. Bole area closely approximates cambium area on the main stem. Thus average thickness of the annual sheath of wood added each year times bole area equals cubic volume increment. This relationship can be useful on either an individual tree basis or an area basis.

2. It is believed that a given bole area level will represent a nearly constant level of competition for most of the life of a stand once peak annual volume increment is achieved. If a constant bole area does mean a constant level of competition, the average thickness of the annual sheath of wood laid on each year would decline with increasing age in direct proportion to the decline in gross cubic volume increment per unit of area.

Trends that have taken place in the Twin Lakes study suggest that a constant bole area level means declining levels of basal area and CCF. However, a 32-year-old thinning study at Pringle Falls has shown that a nearly constant bole area means a rising level of basal area or that basal area rises more rapidly than bole area in relative terms. Also, CCF tended to change nearly in direct proportion to bole area on some plots but not all (Dahms 1971). Failure to measure bark thickness accurately at Twin Lakes in 1964 may be causing some false apparent trends there.

The idea that a constant bole area over time may represent a nearly constant level of competition receives support from the Pringle Falls lodgepole pine thinning study (Dahms 1971) and the Twin Lakes study considered together. Twelve thousand square feet of bole area per acre seems almost enough for the site at Twin Lakes.

At Pringle Falls, trees on the heavily thinned plot that had grown back to 12,587 square feet of bole area per acre by 1966 produced almost exactly as much gross increment as the unthinned check plot during the decade from 1957 through 1966. Stand age went from 78 to 87 years during this period. Thus preliminary indications are that a given level of bole area has similar stand density implications over a broad age range.

Others have thought of bole area as one of the best tools for controlling stand density for research purposes. Smith (1962, p. 102) states "The most logical parameter, bole surface area per acre, was proposed by Lexen (1943)." Once good stand density regimes are worked out in bole area terms, they can be translated into more easily used measures of stand density.

Predicted Increment

Predicted increment figures obtained from the gross yield table (Dahms 1964) agree closely with actual yields obtained during the past 10 years. Entering the gross yield table increment equation with a CCF (density) value of 166, which is the average for the two plots of highest density just before thinning in 1969, gives an estimated per-acre increment of 118.7 compared with an actual of 114.9.

If we enter the gross yield table equation with a CCF value of 189, which is the average density of 32-year-old stands used to develop the equation, the estimated increment figure is 136.1 cubic feet per acre. If we assume that a higher density for the Twin Lakes plots would not increase actual increment, predicted volume increment is 21.2 cubic feet higher than actual. However, if we assume that actual volume increment would increase with increasing density as indicated by extrapolating the volume increment on log of CCF equation (fig. 15), actual increment would rise to 130.7 cubic feet per acre or 5.4 short of predicted. Difference between actual and predicted volume increment ranged from 3.8 to 21.2 cubic feet per acre per year, depending on what assumptions were made, a reasonably good correspondence.

Close correspondence between predicted increment figures from the gross yield table and actual growth figures from the present Twin Lakes study and from the Pringle Falls thinning study (Dahms 1971) leads to the conclusion that managed stand yields can be approximated from a combination of thinning study results and the gross yield table. As an example, a thinning schedule was developed based on the idea that thinning to 12,000 square feet of bole area per acre every 10 years will produce 85 percent of the gross yield table cubic volume increment estimate. 10/ Currently, confidence in such schedules is low. However,

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[10] *This unpublished thinning schedule is on file at the Silviculture Laboratory, Pacific Northwest Forest and Range Experiment Station, in Bend, Oreg. It was developed at the request of the Winema National Forest and the Station's production economics project.*

as more data become available from existing studies, stand models that will permit comparisons between various management alternatives should be possible.

Understory Vegetation

Understory vegetation did not develop vigorously on the Twin Lakes plots (fig. 17). Amount of ground covered in 1970, 11 growing seasons after the first thinning, ranged from a low of 3 percent on one plot to a high of 27 on another and averaged 17.3 percent. If there were any effect of thinning-established tree density regimes on understory vegetation, it was small and completely masked by differences that existed prior to thinning.

Figure 17.–A plot of the middle density (400 trees per acre) with almost no understory vegetation. Photograph taken just before the 1969 thinning.

Snowbrush, other shrubs, grasses and sedges, and forbs ranked in that order in amount of crown cover. Snowbrush was recorded on only three of the 12 plots, but on one it covered 21 percent of the ground.

Soil Moisture

Average annual soil moisture withdrawal was greater at the higher density levels over the period 1961-70 (fig. 18). Differences between levels were significant at the 95-percent confidence level. This is the kind of result that generally is to be expected where forest vegetation density is reduced (Packer and Laycock 1969).

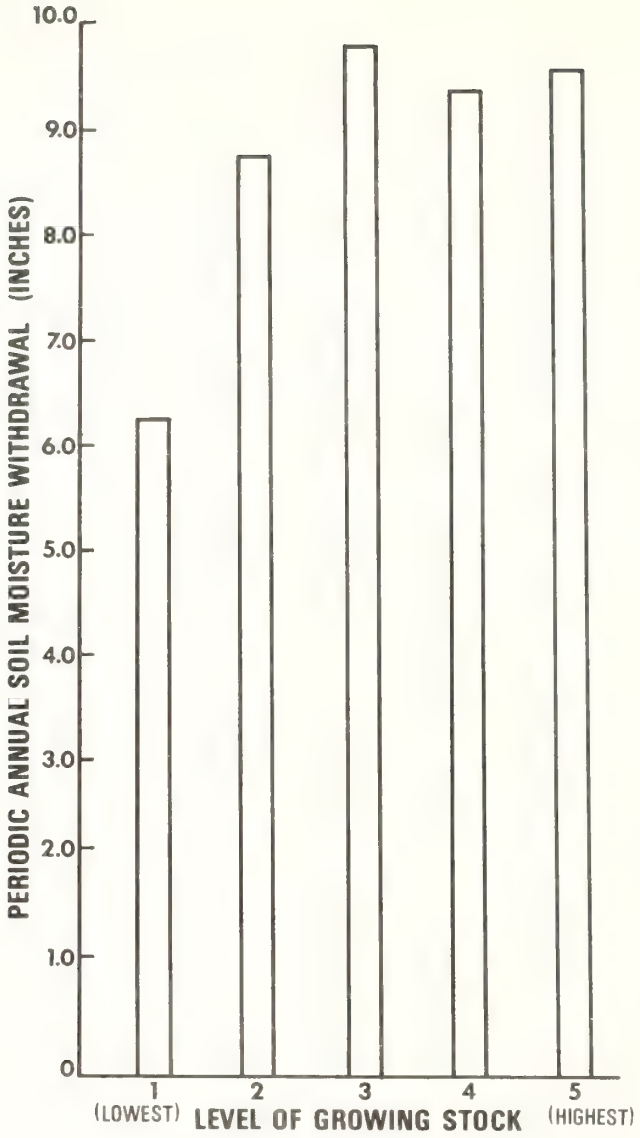

Figure 18.–Periodic annual soil moisture withdrawal by growing-stock level, 1961-70.

Growing-stock level did not affect soil moisture withdrawal consistently every year (fig. 19). In 1961, differences between levels were statistically significant. However, by 1962, crowns and roots had expanded and soil moisture withdrawal at the lower densities had increased relative to that at the higher ones. Consequently, differences were no longer significant. This situation continued until after the thinning in the fall of 1964. During 1965, differences in soil moisture withdrawal were again significant and continued through

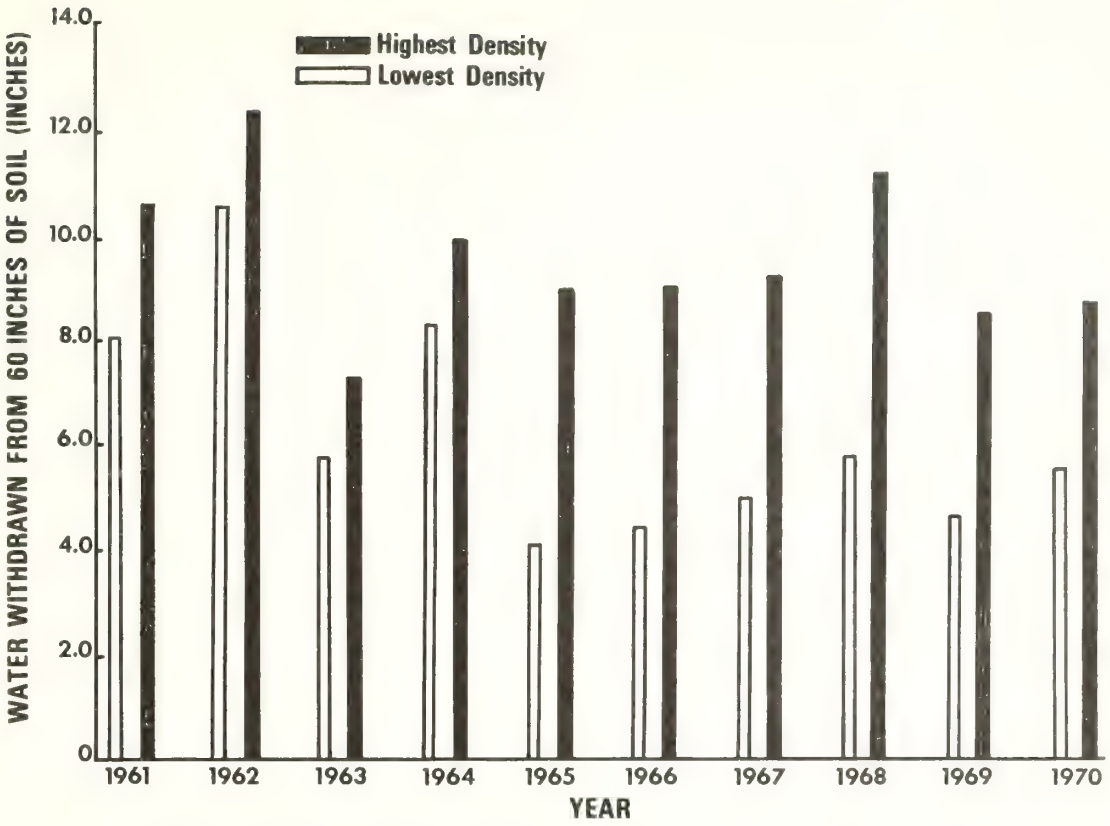

Figure 19.–Inches of water withdrawn from 60 inches of soil at the highest and lowest densities, by years.

1969. Crowns and root systems of the lesser number of trees remaining at the lower densities, after the more drastic 1964 growing-stock reductions, were not able to expand enough to make full use of the available soil moisture before the thinning at the end of the 1969 growing season. This tendency for growing-stock levels to affect soil moisture use differently from year to year was significant well beyond the 99-percent confidence level.

Soil moisture was withdrawn largely from the upper part of the soil during the early part of the season (fig. 20). However, as the summer advanced and most of the water in the upper portion of the soil had been used, soil moisture from the deeper layers was required for transpiration demands. For example, from May 4 to June 16 several times more water was withdrawn from the upper foot of soil than from the deepest measured foot. However, from July 24 to September 19 substantially more was withdrawn from the deepest foot (fig. 20).

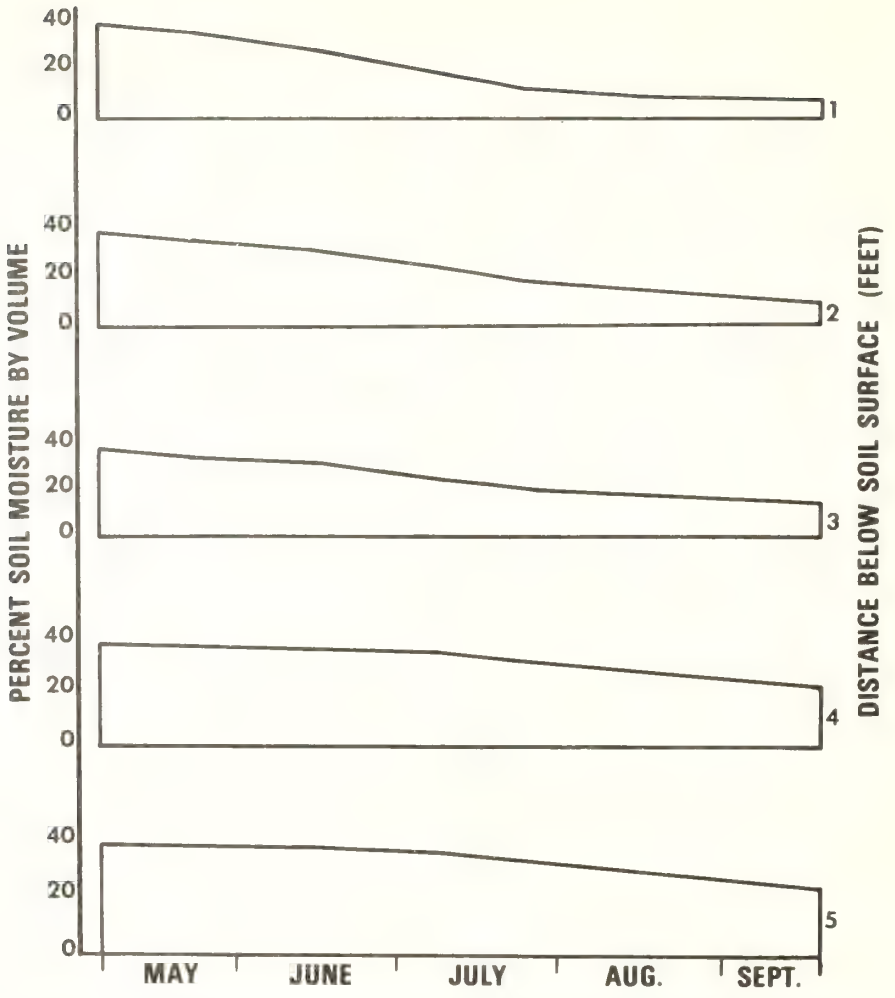

Figure 20.—Average soil moisture percent by volume during the growing season for all treatments, 1961-70.

Stored soil moisture plus precipitation appeared to be adequate to meet the evapotranspiration demand during the growing season. This conclusion is based primarily on the close agreement between the excess of estimated evapotranspiration[11/] over precipitation and actual soil moisture withdrawal (fig. 21). Ability of the trees to obtain water at an undiminished rate through July and into August is further evidence in support of the conclusion that there was enough water to meet the evapotranspiration demand.

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[11] *Potential evapotranspiration was obtained from Johnsgard (1963). His calculation was based on weather records from the Fall River fish hatchery and on the Thornthwaite-Mather procedure. The Fall River weather station is approximately 10 miles from Twin Lakes.*

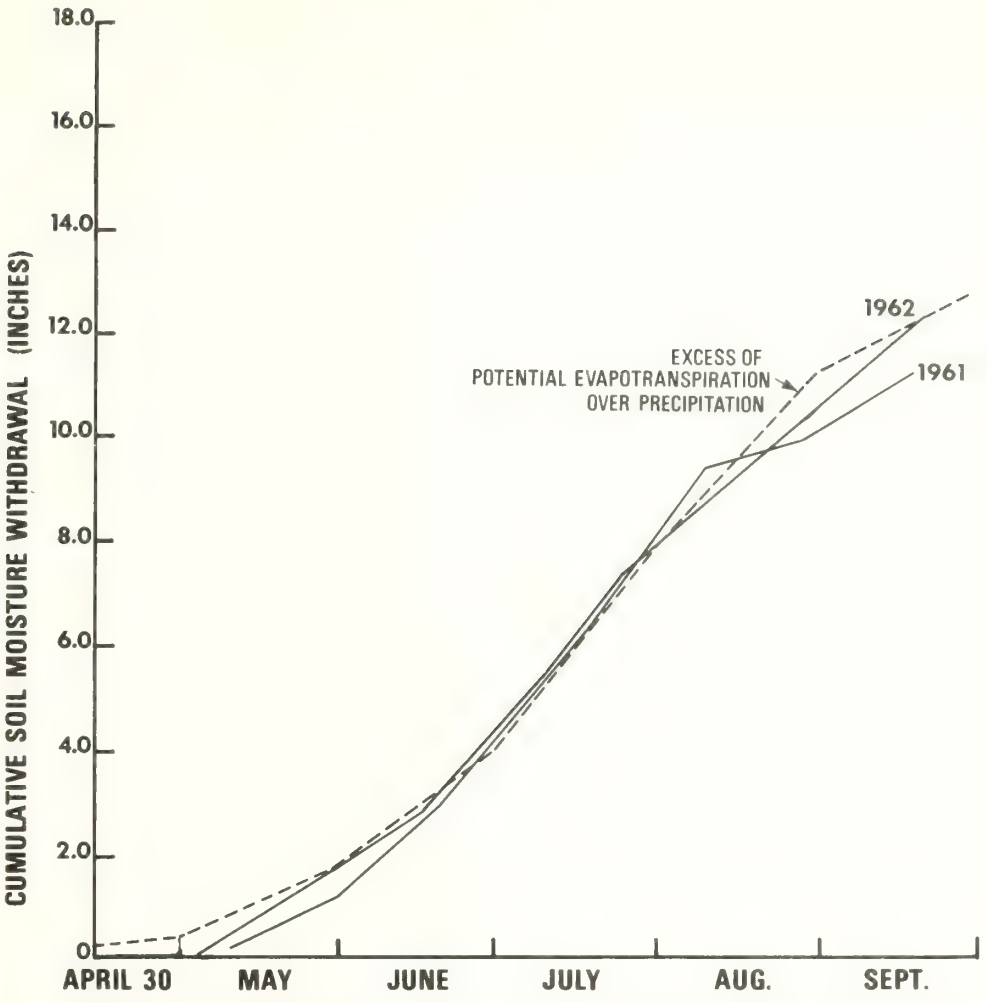

Figure 21.—Seasonal progress of soil moisture withdrawal, compared with potential evapotranspiration, from top 60 inches of soil during 1961 and 1962.

Small differences between actual soil moisture withdrawal and that predicted as the difference between potential evapotranspiration and precipitation are the result of small climatic differences between Fall River and Twin Lakes (see footnote 11), and seasonal variations. The last snow normally melts a week or 10 days later at Twin Lakes than at Fall River. Hence actual soil moisture withdrawal at Twin Lakes was slower in starting than the estimated potential at Fall River. A rainy, cloudy period between August 9 and 28 in 1961 accounts for the sharp drop in soil moisture withdrawal during that period.

DISCUSSION

Stand density control has been effective in transferring wood production from the many small useless stems to a lesser number of more valuable ones. During the 10-year period of the Twin Lakes study, approximately twice as much wood has been added to the 100 largest trees at the lowest density level as at the highest. Even though this comparison would seem to imply that no more than 100 trees can reach usable size, it is reasonably useful because by far the largest part of the usable volume is contained in the 100 largest trees.

One might also visualize the process of transferring wood production onto usable-sized trees by starting with the 85-trees-per-acre spacing treatment. Total cubic volume production is only about one-third of that at the highest density. However, the tree of average diameter (9.1 inches) has already reached usable size. Consequently, all wood produced is on trees that now are or very soon will be merchantable. Furthermore, the rapidly increasing stand density (bole-area, basal-area, etc. increases with tree size) means volume increment will be increasing rapidly relative to the high density treatment.

Although 85 trees per acre may be below the optimum stand density, all trees will be well above minimum usable size before any more thinnings are needed. The current annual production of 42 cubic feet per acre on trees that are or will be usable size is far above the merchantable wood growth obtained in natural stands. If wood growth could be continued at this rate until trees reached an average diameter of 14 to 15 inches (which is likely), annual board-foot production would amount to approximately 210 board feet per acre.

Understory vegetation did not develop as rapidly at Twin Lakes as it did on the Pringle Falls ponderosa pine spacing study. At Pringle Falls there was a definite trend of increasing understory crown density with decreasing number of trees and with the passage of time since thinning. Understory crown density reached a high of 47 percent at 125 trees per acre 9 years after the thinning (Barrett 1970). In contrast, understory vegetation at Twin Lakes showed no relationship to tree spacing and reached an average crown density of only 17 percent in 1970, 11 years after the first thinning.

Nontree understory vegetation may have had a slightly better opportunity to develop on the Pringle Falls study because the understory sapling stand was thinned very soon after the old-growth pine overstory was removed. Consequently, a large amount of new growing space, that the newly thinned suppressed sapling stand was incapable of using immediately, was made available. Because the Twin

Lakes lodgepole pine stand was in a vigorous growing condition, trees left after thinning were probably in a better position to compete with understory vegetation for the new growing space than the Pringle Falls trees.

Other factors also appear to be influencing differences in understory development between the Twin Lakes levels-of-growing-stock study area and the Pringle Falls spacing study. Differences in environment implied by understory species differences between the two areas are almost certainly involved. Observation shows that understory vegetation in the ponderosa pine stand surrounding the lodgepole pine study area is much denser. The ponderosa pine originated following the same 1934 fire that gave rise to the lodgepole pine stand and was thinned in 1957 only 2 years before the lodgepole study area was thinned. The ponderosa pine is growing in the same *Pinus ponderosa/Ceanothus velutinus-Purshia tridentata* community found on the Pringle Falls spacing study area. Sloping topography characterizes the ponderosa pine areas both at Pringle Falls and at Twin Lakes in contrast with the low-lying flat area occupied by the Twin Lakes lodgepole pine study.

Size of the difference in soil moisture withdrawal between low and high density plots at Twin Lakes may have been substantially increased by lack of understory development. Barrett (1970) reported that less soil moisture was withdrawn where understory had been removed than where it had been allowed to develop naturally. He further reported that as crowns and roots of both trees and understory developed with the passage of time, an increasing amount of soil moisture was withdrawn. Thus failure of the understory to expand and substantially replace the transpiring needle surface of cut trees probably explains the large difference in soil moisture withdrawal between stands.

Reduction in amounts of snow and rain intercepted by tree crowns and resulting increases in snow stored on the ground are other effects of thinning discussed by Goodell (1952). Under the circumstances of relatively high precipitation where Goodell carried out his studies, the result was greater water yield. However, where soil water storage capacity tends to be greater than precipitation, the result could be more water for tree growth. No effort was made to assess effect of thinning on tree crown interception of rain and snow or on snow storage at Twin Lakes.

Reasoning suggests that differences in understory vegetation density between the Twin Lakes and Pringle Falls sites may account for differences in tree growth. Barrett (1970) reported that where understory vegetation was allowed to develop naturally, the 62 "best" trees per acre out of 1,000 present grew almost as well as the 62

trees left after removing all others. However, when understory vegetation was removed the 62 trees by themselves grew much more rapidly than the 62 "best." At Twin Lakes both diameter growth and volume increment of the 100 largest trees per acre increased steadily as tree density decreased despite the presence of understory. Differences in understory competitiveness may well be the result of differences in quantity of understory.

Differences in environment implied by differences in vegetation may be the principal reason for variations in understory response to thinning between Twin Lakes and Pringle Falls. If this is true, it will be necessary to assess response of understory vegetation to thinning and its effect on tree growth and soil moisture depletion separately for each of the many soil vegetation types.

Increasing susceptibility of lodgepole pine trees to mountain pine beetle attack with increasing tree size is another factor that may have a bearing on the best stand density regime. Amman (1969) and Roe and Amman (1970) point out that large trees with thick phloem are the most likely to be attacked in natural stands. In the stands investigated, age and tree size were correlated (Roe and Amman 1970). Consequently, the question, how susceptible are fast growing young trees of larger size in managed stands, is still unanswered.

The effect of stand density on soil moisture withdrawal and wood production at Twin Lakes and on understory forage production at other study sites (McConnell and Smith 1970) clearly points to an opportunity for manipulation of forest land output to obtain the products most desired. Very young forests present the best manipulation opportunities. A precommercial thinning may often substantially increase usable wood production and at the same time increase both water and forage production. However, as trees grow in size and nearly all wood produced is being added to usable-sized trees, the stand density reduction required to increase forage and water outputs would be at the cost of reduced wood growth.

The main conclusions that have been reached from the Twin Lakes study are:

1. The excellent growth response of young lodgepole pine to thinning means most of the total possible wood producing capacity can be transferred to the relatively small number of trees that can reach usable size.

2. Understory vegetation did not develop as vigorously at Twin Lakes as Barrett reported at Pringle Falls. Reasoning from Barrett's Pringle Falls results suggests that differences in vegetation development will affect tree growth. Consequently, different understory responses to thinning from one soil

vegetation type to another may trigger different tree growth and soil moisture withdrawal responses.

3. The low stand density that fostered rapid individual tree growth and reduced evapotranspiration drain on soil moisture favored merchantable timber production and may have increased water yield as well at Twin Lakes. However, as trees begin to reach usable size and there is a desire to keep them in full possession of the site, the goal of near maximum wood production is not compatible with reducing transpiration drain on soil water by reducing tree density.

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A lodgepole pine levels-of-growing-stock study showed that individual trees developed longer crowns, grew more rapidly and added more wood to potentially merchantable trees at lower stand densities, but total wood production was less. Evapotranspiration drain on soil moisture was also less at the lower stand densities.

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SALTY BARK AS A SOIL AMENDMENT

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ABSTRACT

Bark from Douglas-fir logs floated in sea water contained 0.75 to 1.94 percent salt (NaCl). Leaching by natural and simulated rainfall and by soaking readily removed this salt. Bush bean and tomato plants were grown in the greenhouse on a sandy loam soil to which bark of three different proportions of salt was applied as a mulch and as an incorporation at the rate of 40 tons per acre. Mulches containing 0.75 and 1.41 percent salt had little effect on beans but bark containing 1.94 percent salt was slightly depressive; all the incorporations were depressive. Tomato plant yields were reduced by all the bark treatments, most severely by the incorporations.

Use of salty bark at usual rates on the soil can injure salt sensitive plants. Mulches would be less hazardous than incorporations. Chunk sizes would probably cause no toxic effects. Most soil microbes and their essential activities are not likely to be appreciably influenced by salt leached into the soil from salty bark.

Keywords: Forest products research, bark, saline water, plant growth inhibitors.

INTRODUCTION

About 5 million tons of tree bark are produced annually as a byproduct of the wood-using industry of the Pacific States. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is the principal tree species involved. Much of this bark is burned, a practice which can contribute to air pollution in areas of mill concentration. Alternative methods of disposing of tree bark include agricultural or horticultural use as mulch or soil conditioner. Several hundred thousand tons of bark are now being so used.

An appreciable portion of the total production of such bark comes from logs that have been stored or transported in salt water. The salt [1/] content of bark from such logs may be as high as 3.5 percent (table 1), depending on bark moisture content, extent of exposure to sea water, dilution of sea water by fresh water, bark thickness, flotation pattern of the log, scuff marks, dead knots, or marine borer action.

A range of 0.75 to 1.94 percent NaCl was found in a series of samples submitted to us for study (table 2). Logs from which these samples came floated in salt water for periods ranging from 14 to 75 days, then were stored in brackish bay water until sawn.

Agricultural or horticultural use of bark containing appreciable amounts of salt has been questioned. Highly soluble NaCl eventually can leach from the bark into the soil. If all the salt in bark containing NaCl at levels indicated in our samples were to be leached into underlying soil by rain or irrigation, NaCl concentrations of 400 or more parts per million (p.p.m.) might be reached, depending on the depth of soil considered. Toxicity, especially to salt-sensitive plants, might thus develop (Bernstein 1964b).

The main effect of high salinity on plant growth is to make more difficult the uptake of water by plant roots. Factors determining the possibility of reaching toxic levels include initial salt content of bark, bark particle size, amount and distribution of rain or irrigation water, soil type, and kind and age of plant.

Because of the many factors involved, it is difficult to forecast any potential harm to plants that salty bark would

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[1/] Throughout this paper "salt" refers to sodium chloride (NaCl). These terms are used interchangeably.

Table 1.--Salt (NaCl) in bark of salt-water-transported logs

Species and weeks in sea	NaCl		
	Log No. 1	Log No. 2	Log No. 3
	Percent		
Douglas-fir:			
3	0.48	0.45	1.32
6	.52	2.22	.74
12	.96	2.04	1.11
25	1.23	--	1.59
Western hemlock:			
2	1.06	1.05	1.07
6	1.54	2.06	1.98
12	--	2.45	3.50
25	--	3.27	--
Western redcedar:			
2	1.58	1.79	1.74
6	2.59	2.44	2.98
12	3.36	3.50	2.84
25	--	1.46	2.00

Source: MacLean, H., and B. F. MacDonald (1968). Salt distribution in sea-water transported logs. Inform. Rep. VP-X-45, 23 p. Forest Prod. Lab., Vancouver, B.C.

Table 2.--Salt (NaCl) in bark from salt-water-floated sample logs

Sample number and species	Total time rafted[1/]	Time stored in salt water	NaCl	
			Investigator's analysis	Commercial laboratory analysis
	--Months--	*---Days---*	*----------Percent----------*	
1, Douglas-fir	2	14	0.75	0.65
2, Hemlock	2	70	1.16	.98
3, Douglas-fir	4	75	1.56	1.23
4, Hemlock	12	20	1.27	1.31
5, Douglas-fir	11	15	.88	.86
6, Hemlock	11	20	1.29	1.14
7, Douglas-fir	16	15	.80	.70
8, Douglas-fir	--	--	.92	.80
9, Douglas-fir	--	--	.98	1.17
10, Douglas-fir	--	--	1.94	1.80
11, Douglas-fir	--	--	1.41	1.42
12, Douglas-fir	--	--	.86	.85
13, Douglas-fir	--	--	1.44	1.31
14, Douglas-fir	--	--	1.63	1.72

[1/] In brackish water at mill.

cause when added to the soil. The salt would be readily dissolved from bark, but the concentration around plant roots would be determined largely by the amount of water applied. Light rainfall or irrigation might only moisten or saturate the bark particles without washing out any salt. Moderate wetting could leach toxic amounts into the upper root zone. On the other hand, greater amounts of water could carry the salt to greater depths and dilute the solution below toxic levels.

The analyses and experiments described in this paper were made to determine the effects on plant growth of applying salty bark to soil, either as a mulch or as an incorporation.

LITERATURE REVIEW

The rate of movement of leached salt into the soil depends largely on soil texture and structure; downward movement would be rapid in sandy soils but very slow in clay soils. Shaw (1927) found that 6 inches of water percolated uniformly throughout a fine sandy loam soil, giving a moisture content of 20 percent, to a depth of 18 inches in 24 days. The temperature-humidity-light complex as affecting transpiration is also important because it influences absorption of NaCl (Lipman et al. 1926, Nieman 1962). Ahi and Powers (1938) found that temperature is a dominant factor in the germination and growth of plants under saline conditions.

The actual concentration of NaCl that would prove injurious in the soil varies with kind and variety of plant, stage of growth, and climatic conditions (Bernstein 1964a, 1964b, U.S. Salinity Laboratory 1954). Chloride exerts specific toxicity to some tree and vine crops, whereas in combination with sodium as NaCl, the effects are more general. The relative tolerance of crop plants to salt places asparagus, cotton, and beets in the high salt tolerant group. Strawberries are very sensitive to salinity (Ehlig and Bernstein 1958). On the other hand, asparagus growth is actually stimulated by salt applications as high as 500 pounds per acre (Rudolfs 1921a). Although 5 to 6 tons of salt per acre is an effective herbicide for many kinds of weeds, absorption of small quantities of chloride ion can stimulate growth (Rudolfs 1921b).

Tomatoes, sweet corn, peas, and some clovers are of medium salt tolerance, while green beans, radishes, and celery are of low salt tolerance. From field plot studies, Bernstein (1964b) found that 1,000 p.p.m. salt reduced a bean crop 10 percent, and tomatoes withstood about 20,000 p.p.m. before a similar reduction in yield occurred. Most plants have more salt tolerance as they approach maturity; they are more easily damaged when they are seedlings.

Salt tolerance of roadside trees along New Hampshire highways salted for deicing has been discussed by Schortle and Rich (1970). Twelve species listed as salt-tolerant showed little or no injury to chloride concentrations ranging from 200 to 11,500 p.p.m. Ten intolerant species were slightly to severely injured by a mean concentration of 9,300 p.p.m. chloride. Considerable variation in salt tolerance was found within as well as between species. Holmes (1961) found that winter road salting probably does no great harm to various hardwoods and white pine in Massachusetts. Damage to white pine from roadside salting has been reported by Smith (1970).

Injury to soil microbes from excessive salt would be detrimental to soil fertility. However, little or no harmful influence of salty bark on soil microbial activities is

likely. Most bacteria are relatively insensitive to wide osmotic pressure changes and can adjust to wide changes in the concentration of solutes. Marine bacteria grow in the oceans, containing about 3.5 percent salt; some grow in the Dead Sea containing 25 percent salt, while some halophiles develop on nearly dry sea salt and on salted hides and fish.

Greaves (1916) observed that 5 to 7 p.p.m. NaCl slightly increased ammonification in a sandy loam soil; only much greater concentrations were increasingly depressive, reducing ammonium formation by 90 percent at 5,000 p.p.m. Brown and Johnson (1918) found that ammonification was stimulated by 50 p.p.m. NaCl but was decreased by 100 p.p.m. According to studies by Gibbs, Batchelor, and Magnuson (1925) 1,000 to 4,000 p.p.m. NaCl added to a neutral silt loam soil depressed ammonification and nitrification. Only the highest rate, 4,000 p.p.m., reduced crop yield of wheat in the greenhouse, but a following crop of wheat on the originally treated soils was increased by the residual salt; however, some toxicity to ammonification and nitrification remained. Studies by Brown and Hitchcock (1917) showed that nitrification in normal soils was stimulated by small amounts (50 p.p.m.) of NaCl; above 100 p.p.m., the salt became toxic.

Hendry (1918) found that 2,000 to 8,000 p.p.m. NaCl in liquid added to quartz sand cultures caused injury to bean and cowpea plants and also caused a decrease in the number and size of nodules produced by the symbiotic nitrogen-fixing *Rhizobium* bacteria. In our greenhouse study, salty bark reduced the number of root nodules on inoculated beans in inverse proportion to the NaCl content, while equivalent amounts of sea salt alone almost completely prevented nodulation.

In a clay soil reclaimed from the sea in the Netherlands, Schreven and Harmsen (1968) found that fresh water leached the salt content from about 18 percent to nearly 5 percent, 18 months after the sea had receded. During this time, the bacterial count increased from 65,000 per gram to 15 million; 6 months later this count doubled. In a silt loam soil similarly reclaimed, the salt decreased from about 3.5 percent to nearly zero after 3 years, while the bacteria increased from about 1 million to 60 million per gram. The first period after the sea water had receded was always characterized by an increase in bacteria, the increase being approximately proportional to the decrease in moisture and salt content and the increase in aeration of the soils.

STUDY METHODS

Sample Preparation and NaCl Analysis

Fourteen 10-pound samples of bark from salt-water-transported logs were supplied by Publishers Forest Products Company of Anacortes, Washington.[2/] The samples contained an estimated 10 to 20 percent wood splinters and particles.

Samples were air-dried at 28° C., 31-percent relative humidity, and ground in a Sprout-Waldron single disk attrition mill to pass a 10-mesh sieve. Subsamples taken by quartering were ground in a shatterbox to -100 mesh for NaCl analysis.

Water content was obtained from loss by drying to constant weight at 105° C. All results are expressed on the ovendry basis.

[2/] Mention of a company or product does not imply endorsement by the U. S. Department of Agriculture to the exclusion of other companies or products.

Chloride was determined by the lime-fusion method (American Wood Preservers Association 1969). NaCl percentages were calculated from the chloride values.

Leaching Studies

Several trials were made to determine how much and how rapidly NaCl could be leached from the bark.

1. A 50-gram sample, ovendry basis, of bark of a salt-water-floated Douglas-fir log, -10 mesh, 1.41 percent NaCl, 6.83 percent H_2O, was placed in a 1-liter Erlenmeyer flask with enough distilled water to give a 1:10 dilution, mechanically shaken 24 hours, and filtered through Whatman No. 1 paper on a Buchner funnel. The filtrate was analyzed for NaCl. This procedure was repeated four times.

2. From a salt-water-floated Douglas-fir log, 1.44 percent NaCl, a 2-inch layer of -1/2-inch-mesh bark screened from the bulk sample was placed on a 9- by 9-inch wooden frame with a 100-mesh brass screen bottom. This held 985 g. of sample containing 103.1 percent water, the ovendry equivalent being 485 g. The frame with the bark was placed over a pan and sprinkled for 5 minutes with 1,327 ml. distilled water, the equivalent of a 1-inch rainfall over the 9- by 9-inch area. The collected leachate was analyzed for NaCl. This procedure was repeated six times at different times.

3. Salt was leached from 435 g. of bark chunks, ovendry basis, nominally 1- to 2-inch size, 1.63 percent NaCl, 104 percent H_2O, from a salt-water-floated Douglas-fir log, after soaking in 2 liters of distilled water for 24 hours. The bark was then drained and NaCl determined on an aliquot of the drainage after clarification with activated charcoal. NaCl absorbed by the charcoal was found to be negligible. The soaking and draining were repeated seven times.

4. A 2-inch layer of the chunks was exposed to natural rainfall on a 2- by 9- by 10-inch 1/4-inch mesh galvanized screen that fit snugly into the mouth of a polyethylene pail. The percolate was removed for analysis five times within the total period of exposure to 14.4 inches of rain during 54 days from November 18 to January 11.

5. Salt was leached from bark mulch and from soil-incorporated bark from harvested greenhouse pots (table 7).

After beans and tomatoes were grown on soil with a 2-inch mulch of -10-mesh bark from a salt-water-floated Douglas-fir log, 1.41 percent NaCl, and in soil with the bark incorporated at the rate of 40 tons per acre, ovendry basis, the mulch was carefully removed from one of the pots; and 10.0 g. of mulch, ovendry basis, was subjected to extraction for chloride three successive times with 100 ml. distilled water by mechanically shaking 24 hours each time. Each extract was clarified by filtration through Whatman No. 1 paper and analyzed for chloride. Soil under the mulch and soil with bark incorporated were treated in like manner.

All leaching studies were unreplicated; thus, analyses of variance were not possible. It is, however, expected that repeated applications of these studies would produce the same general conclusions.

Plant Growth Studies

To determine if salty bark would have a harmful effect on plant growth, garden beans (Burpee's Stringless Green Pod)

and tomatoes (Earlibell) were grown in pots of Newberg sandy loam in the greenhouse. This soil was chosen because it is relatively low in the major nutrients, nitrogen and phosphorus. With such a soil, it was believed the salt effects would be more pronounced.

Six-inch polyethylene pots with drainage holes were filled with 750 g. soil, ovendry basis, and treated in triplicate. Treatments with salt-free bark from the Willamette Valley and sea-salt[3] in amounts equivalent to NaCl added with the three salty barks used were included for comparison.

In one series, 10 bean seeds, inoculated with *Rhizobium phosaeoli*, were planted in each pot on July 6; when seedlings were 1 to 2 inches tall, they were thinned to three. At the end of September, after 84 days, the plants were cut at ground level, air-dried, and weighed. The roots were harvested separately, air-dried, and weighed. In all cases, the roots were found to be nodulated by the *Rhizobium*.

In a like series of pots, 10 tomato seeds were planted; seedlings were later thinned to three. The plants were harvested in October after 107 days of growth after some flower buds had developed.

All pots were watered with tap water from time to time to keep the soil moist without causing noticeable loss by drainage.

Even in the control pots, plant growth after 6 weeks was not as vigorous as expected, so solutions of ammonium nitrate and monopotassium phosphate were added to each pot at rates of 100 pounds nitrogen, 100 pounds phosphorus, and 126 pounds potassium per acre. This booster had only slight effect.

Harvested tops and roots of bean and tomato plants were air-dried at 28° C., 31-percent relative humidity, and weighed. Sound nodules on bean plant roots also were counted; however, the counts do not represent earlier nodulation because many more or less disintegrated nodules were found. All data were subjected to an analysis of variance.[4]

Bacterial Tolerance Studies

Thirty-six bacteria were isolated from several different soils by plating procedures (Fred and Waksman 1928), identified (Society of American Bacteriologists 1957, Breed, Murray, and Smith 1957), and tested for growth in nutrient broth containing 2, 7, and 10 percent NaCl.

RESULTS AND DISCUSSION

Leaching Studies

Nearly 90 percent of the salt was removed by the first extraction of bark of a salt-water-floated Douglas-fir log (table 3). All the salt was removed after three extractions.

Sprinkling the bark sample in table 4 with water equivalent to 6 inches of rainfall resulted in removal of more than 90 percent of the salt (table 4). Volume of the first leachate was low, because most of the initial sprinkling was required to saturate the bark. The second leaching removed a major portion of the total salt.

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[3] Salt from sun-evaporated sea water. Hain Pure Food Co., Inc., Los Angeles, California.

[4] The design was a one-way analysis of variance with individual treatment effects isolated with a set of orthogonal comparisons. Response surface effects from the levels of salt in water and in bark were analyzed.

Table 3.--Salt (NaCl) extracted from bark sample No. 11,[1/]
-10 mesh, by shaking with distilled water[2/]

Extraction number	NaCl	
	In extract	Extracted from bark
	----Mg.----	*------Percent------*
1	623	88.5
2	80	11.3
3	2	.3
4	0	.0
Total	705	100.1

[1/] 50.0 g., ovendry basis, 1.41 percent NaCl, 6.83 percent H_2O.

[2/] 4 successive 24-hour periods, with 1:10 dilution each time.

Table 4.--Salt (NaCl) leached from bark sample No. 13,[1/]
-1/2-inch mesh, by successive sprinklings,
each simulating 1 inch of rainfall[2/]

Interval between sprinklings	Volume of leachate	NaCl in leachate		Bark NaCl content removed
	--Ml.--	*-Mg.-*	*P.p.m.*	*-Percent-*
0 hours	180	652	3,622	9.3
50 "	1,435	4,377	3,050	62.7
24 "	1,000	900	900	12.9
24 "	1,000	370	370	5.3
24 "	980	88	90	1.3
48 "	1,480	59	40	.8
Total	6,075	6,449	1,061	92.3

[1/] 1.44 percent NaCl.

[2/] 1,327 ml. distilled water from fine spray in 5 minutes each time. Bark layer of 985 g., 2-inch deep by 9- by 9-inch, supported on 100-mesh screen, 103.1 percent H_2O; bark equivalent to 485 g. ovendry basis.

Progressively lesser amounts were removed thereafter until the sixth time, when less than 1 percent salt was found in the leachate. If all the salt leached were uniformly distributed in the surface 6-2/3 inches of a soil and not further diluted by soil moisture, the NaCl concentration would be 1,061 p.p.m.

With the sample bark chunks in table 5, nearly half of all the salt was removed by the first soaking, most of it by three soakings, and essentially all by five successive treatments; less than 1 percent was found in the final removal (table 5). These results indicate that salt in bark chunks also is readily removed by water.

Exposure of bark chunks to natural rainfall also resulted in nearly complete leaching of salt (table 6). During the first 12 days, 4.5 inches of rain leached 81.8 percent of the bark's salt content. Thereafter, the amount of salt leached decreased progressively at a rapid rate. The 14.4 inches of rain during 53 days removed 97.5 percent of the total salt.

During each period, rainfall was collected for chloride determinations. Only during the second and third periods (table 6), which were unusually stormy, was chloride found, equivalent to 1.2 p.p.m. NaCl in each case. This value is close to the mean of those recorded by Ellsworth and Moodie (1964) for rainwater collected during winter months of 1961, 1962, and 1963 at Vancouver, Washington, similar to Corvallis, Oregon, in distance from the ocean.

No appreciable loss of salt occurred when pots containing bark mulch and soil-incorporated bark were watered in the greenhouse (table 7), because the watering regime was adjusted to provide good plant growth without inducing drainage. During the growing season from July to November, the pots were watered about 30 times with 150 to 200 ml. tapwater each time; this kept the soil adequately moist but never oversaturated. This treatment removed 35.7 percent of the bark salt from the mulch. Slightly more than this was recovered from the underlying soil, probably due to sampling rather than analytical errors.

Results of salt removal by the several methods are summarized in table 8. Although the different methods are not directly comparable, it is evident that the salt is more readily removed from finely divided bark which has a greater surface area exposed. However, complete removal of salt from even the chunks can be effected, though more slowly, by more water. Although these experiments were not replicated, it is expected that results from repeated samples would be consistent.

The relative ease with which salt was removed from the bark samples (tables 3-6) was comparable to the rapid rate of removal of salt from polder soils after reclaiming from the Zuyder Zee in the Netherlands (Schreven and Harmsen 1968). After soil was flooded with fresh water for 1 year, crops could be grown on the polders.

Plant Growth Studies

As the amount of salt in bark increased (table 9), growth of tops, roots, and nodules of beans and tops and roots of tomatoes decreased significantly in a linear manner (tables 10, 11).

Comparison of the bark as a mulch with bark incorporated shows that growth of bean tops and tomato tops and roots was significantly lower with bark incorporations. Bean root weights were not different between the two methods of bark application.

Table 5.--Salt (NaCl) soaked from chunks[1/] of bark sample No. 14 by distilled water[2/]

Soaking time	Volume of drainage	NaCl in drainage		Bark NaCl content removed
	--Ml.--	*-Mg.-*	*P.p.m.*	*-Percent-*
1 day	1,800	3,431	1,906	47.1
1 day	1,910	1,077	564	14.8
1 day	1,915	1,702	889	23.4
10 days	1,510	598	396	8.2
16 days	1,330	299	225	4.1
13 days	1,390	118	85	1.6
12 days	1,570	61	39	.8
Total	11,425	7,286	--	[3/]102.8

[1/] 1- to 2-inch nominal dimension, 435 g., 1.63 percent NaCl.

[2/] 7 successive soakings, with 2-liter volumes each time.

[3/] Total NaCl removed slightly exceeds 100 percent of that originally present, due to accumulation of positive analytical errors.

Table 6.--Salt (NaCl) leached from chunks[1/] of bark sample No. 14, by rainfall

Exposure number and time	Rainfall		NaCl in leachate		Bark NaCl content leached
	Volume	Volume of leachate			
	Inches	*--Ml.--*	*-Mg.-*	*P.p.m.*	*-Percent-*
1st, 12 days	4.5	6,660	7,066	1,060	81.8
2d, 8 days	3.1	5,020	783	156	9.1
3d, 15 days	2.2	3,170	304	96	3.5
4th, 6 days	3.5	5,220	188	36	2.2
5th, 12 days	1.1	1,700	77	45	.9
Total, 53 days	14.4	21,770	8,418	[2/]387	97.5

[1/] 1 to 2 inches (nominal dimension) 2 inches deep on 9- by 10-inch, 1/4-inch mesh screen; 530 g., 1.63 percent NaCl.

[2/] In total leachate volume.

Table 7.--Salt (NaCl) in bark mulch,[1] soil,[2] and combination[3]

Extraction number	NaCl			
	Found[4]	In total mulch, 32.1 g.		
		Found[4] x 32.1/10	Original	Extracted
Bark mulch:[1]	--Mg.--	---Mg.---	---Mg.---	-Percent-
1	43.9	140.9	--	33.3
2	3.1	10.0	--	2.4
3	.0	.0	--	.0
Total	47.0	150.9	423	35.7

Extraction number	NaCl				
	Found[4]	In total soil, 750 g.		In soil and mulch	
		Found[4]	x 750/20	Added	Found[4]
Soil under mulch:[2]	--Mg.--	--Mg.--	-P.p.m.-	--Mg.--	--Mg.--
1	7.3	273.8	365	--	--
2	.6	22.5	30	--	--
3	.0	.0	0	--	--
Total	7.9	296.3	[5]395	423	447

Extraction number	NaCl				
	Found[4]	In total soil plus bark		Added to soil by bark	
		Found[4]	x 780/20		
Soil with bark incorporated:[3]	--Mg.--	--Mg.--	-P.p.m.-	--Mg.--	-P.p.m.-
1	10.7	417.3	535	--	--
2	.6	23.4	30	--	--
3	.0	.0	0	--	--
Total	11.3	440.7	565	423	564

[1] Mulched with 2 inches -10-mesh bark sample No. 11, 1.41 percent NaCl, at 40 tons per acre. 10.0 g. mulch subjected to extraction 3 successive 24-hour periods with 100 ml. water each time, on mechanical shaker. NaCl determined on total filtrate through Whatman No. 1 paper on Buchner funnel.

[2] Salt in soil under mulch. 20.0 g. extracted as for the mulch.

[3] Soil plus bark sample No. 11, -10 mesh, at 40 tons per acre incorporated. 20.0 g. extracted as for mulch.

[4] Found by chemical analysis.

[5] Leached from mulch by watering in the greenhouse 30 times with 150 to 200 ml. water each time during 114 days. Represents 64.3 percent of NaCl originally present in the mulch.

Table 8.--Influence of bark particle size on amount of salt (NaCl) removed by leaching or soaking

Particle size	NaCl	NaCl content removed
	Percent	
-10 mesh	1.41	[1/] 100.1
-10 mesh	1.41	[2/] 64.3
-1/2-inch mesh	1.44	[3/] 92.3
1- to 2-inch mesh	1.63	[4/] 97.5
1- to 2-inch mesh	1.63	[5/] 102.8

[1/] By 3 successive 24-hour 1:10 extractions with distilled water (table 3).

[2/] By leaching from 2-inch mulch, -10-mesh bark in greenhouse, watering 20 times with 150 ml. each time during 114 days (table 7).

[3/] Three successive simulated 1-inch rainfalls in laboratory at 24-hour intervals (table 4).

[4/] 14.4 inches of rainfall, 53 days (table 6).

[5/] Soaking by 7 successive 2-liter volumes distilled water (table 5).

Table 9.--Soil treatments for study of effect of Douglas-fir salt-free and salty bark[1/] on growth of bean and tomato plants in the greenhouse

Treatment	NaCl in bark	NaCl added to soil
	Percent	*P.p.m.*
Soil only	0.00	0
Mulches at 40 tons per acre:		
Inland bark	0.00	0
Bark No. 7	.75	300
Bark No. 11	1.41	564
Bark No. 10	1.94	776
Incorporated at 40 tons per acre:		
Inland bark	.00	0
Bark No. 7	.75	300
Bark No. 11	1.41	564
Bark No. 10	1.94	776
Sea salt alone:		
Sea salt[2/]	--	300
Sea salt[2/]	--	564
Sea salt[2/]	--	776

[1/] -10 mesh.

[2/] 99 percent NaCl.

Table 10.--Dry weight yield of bean plant tops and roots in the greenhouse

Treatment	NaCl added to soil	Dry weight[1/]		Root nodules[1/]
		Tops	Roots	
	--P.p.m.-	*----------G.----------*		*------Number------*
Soil only	0	5.33	0.93	5
Mulches:				
Inland bark	0	6.40	.98	7
Bark No. 7	300	5.67	.93	4
Bark No. 11	564	5.43	.97	3
Bark No. 10	776	4.33	.68	2
Incorporations:				
Inland bark	0	4.03	1.13	8
Bark No. 7	300	4.33	1.13	5
Bark No. 11	564	3.20	.77	2
Bark No. 10	776	2.80	.73	3
Sea salt alone:				
Sea salt	300	3.87	.63	0
Sea salt	564	2.33	.35	1
Sea salt	776	2.30	.28	0

[1/] Mean of three pots.

Table 11.--Dry weight yield of tomato plants in the greenhouse

Treatment	NaCl added to soil	Dry weight[1/]	
		Tops	Roots
	----P.p.m.----	*----------G.----------*	
Soil only	0	1.03	0.22
Mulches:			
Inland bark	0	.37	.12
Bark No. 7	300	.44	.18
Bark No. 11	564	.50	.20
Bark No. 10	776	.63	.23
Incorporations:			
Inland bark	0	.03	.03
Bark No. 7	300	.04	.02
Bark No. 11	564	.01	.01
Bark No. 10	776	.01	.01
Sea salt alone:			
Sea salt	300	.67	.13
Sea salt	564	.56	.10
Sea salt	776	.57	.09

[1/] Mean of three pots.

A test was made for the presence of a bark treatment by salt interaction. The presence of such an interaction would identify a difference in the response of the plants under the different salty bark treatments to increasing levels of salt. Growth response of tomato tops and roots to salt in bark was significantly different for bark mulch as opposed to bark incorporation. Lesser growth with incorporated bark is believed due to nitrogen deficiency induced by bark mixed with the soil. A mulch is in contact only with the surface of the soil and exerts little immediate influence on nutrition of microbes in the bulk of the soil. Thus, there is little if any competition with plant roots for available nitrogen as would occur with an incorporation of any material having a wide carbon-to-nitrogen ratio.

With sea salt alone, yields of bean tops and roots decreased linearly as salt concentration increased. Tomato top and root growth differences were not statistically significant.

Yields of bean tops, roots, and nodules were significantly less for the average level of sea salt alone applied to the soil than for the average levels of salt in bark. Bernstein and Ayers (1951) observed that green beans had the lowest degree of salt tolerance found in any of the number of truck crops tested. Salt in bark, even though readily leached, may not enter the soil solution as readily as does free salt. Tomato top yields were appreciably reduced by all the bark mulches; the incorporations were much more restrictive.

Not only did the bark mulches lessen depressive influence of the salt but also apparently allowed stimulation by the chloride ion which may have liberated some plant nutrients by an exchange process (Greaves 1916; Rudolfs 1921a, 1921b).

Bacterial Studies

In the presence of 10 percent NaCl, 26 of the isolants grew well; eight grew in the 7-percent concentration but failed to develop in 10 percent NaCl; and only two failed to grow at NaCl concentrations of 2 percent and above (table 12). This indicates that many of the common soil bacteria would not be inhibited by the maximum possible NaCl concentration leached from salty bark applied to the soil.

Salt Tolerance of Soil Molds

Tresner and Hayes (1971) recently reported the NaCl tolerance of 975 species of terrestrial fungi. Only a few of these could tolerate less than 5 percent NaCl; species of *Penicillium* and *Aspergillus*, usually the most abundant molds in soil, were most resistant and the majority were able to grow in the presence of 20 percent or more NaCl.

CONCLUSIONS

Percent of NaCl found in bark from salt-water-floated Douglas-fir logs ranged from 0.75 to 1.94. This salt is readily leached by rainfall or irrigation. Use of such bark for mulching or soil conditioning at usual rates of about 40 tons per acre could result in injury to salt-sensitive plants if leaching was sufficient only to concentrate the salt in the upper root zone. Salty bark ground to nominal 1/4- to 1/2-inch size commonly used for horticultural purposes offers less hazard as a mulch than as an incorporation. Chunk sizes used for walkways and decorative purposes would probably have no toxic effects. Salt leached from salty bark mulches or incorporations would have no appreciable effect on soil microbes and their essential activities.

Field trials with different kinds of plants under a variety of conditions will be required for more definite recommendations on the safe use of salty bark.

Table 12.--Tolerance of some common soil bacteria for salt (NaCl)

Bacterium	Number of isolants tested	NaCl percent concentration		
		2	7	10
Bacillus agrestis	1	–	–	–
Bacillus badus	1	+	–	–
Bacillus cereus	3	+	+	+
Bacillus coagulans	2	+	+	–
Bacillus firmus	2	+	+	+
Bacillus laterosporus	2	+	+	+
Bacillus megaterium	2	+	+	+
Bacillus pumulis	1	+	+	+
Bacillus subtilis	8	+	+	+
Bacillus subtilis aterrimus	2	+	+	+
Bacillus subtilis niger	1	+	+	+
Micrococcus capsulatus	1	–	–	–
Micrococcus caseolyticus	1	+	+	+
Mycobacterium brevicale	1	+	+	+
Pseudomonas geniculata	1	+	+	–
Soil diphtheroid	5	+	+	+
Soil diphtheroid	2	+	+	–

NOTE: – indicates no growth. + indicates growth comparable to that in nutrient broth containing no added NaCl.

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1972
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A CLASSIFICATION OF FOREST ENVIRONMENTS IN THE SOUTH UMPQUA BASIN

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ABSTRACT

Forest environments are classified by elevation, temperature, moisture, potential solar radiation, and soil type. Broad elevation classes are derived from topographic maps or altimeter measurements, measured temperature and moisture conditions are related to vegetation by using plant indicator species (illustrated), and tabular values are employed in estimating potential solar radiation. A series key is included for identifying soil types. Future correlations of silvicultural practices with environmental classes will facilitate optimal prescription for each forest environment in the basin.

Keywords: Classification, environment, indicator plants, temperature, moisture, solar radiation, soil series.

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INTRODUCTION

Land management techniques are numerous and well known, but knowledge of where and how to use these techniques often is inadequate. The silvicultural methods used by foresters in the Pacific Northwest exemplify this predicament. Silviculture largely consists of applying standard techniques to various forest stands. Unfortunately, silvicultural techniques are not universally applicable. They should be selected and modified to fit the environment of each individual forest stand. For example, clearcutting and planting produce healthy young forests in some environments but result in nonstocked brushfields in others. The techniques of wildlife management, recreation, and judicious wilderness use, like those of silviculture, should be tailored to fit the environments in which they are applied. Classification of forest environments and development of management practices for each environmental class will result in greatly improved forest land management.

Environments are not easily classified. Many interacting factors combine to produce any environment. Measuring all of these directly is impractical, even in a simple environment. For example, Penman (1965) recorded solar radiation, temperature, humidity, precipitation, soil moisture, wind velocity, and carbon dioxide in a barley field. The resulting data were expensive to obtain and difficult to integrate meaningfully. Furthermore, they were relevant to only a small field on a single summer day. Measuring all of the environmental factors in a large, complex area like the South Umpqua basin would be infeasible. Indirect measurements of site capacity (Rennie 1963) or the environmental complex as a whole are more practicable.

Among the simplest indirect measurements of site capacity are the site indexes of commercial tree species--where local site index curves are available for the area being evaluated (Jones 1969). Unfortunately, local site index curves are not available for the South Umpqua basin, and the curves constructed from trees measured in northwestern Oregon and Washington probably do not accurately portray South Umpqua growth patterns. Furthermore, site indexes furnish little environmental information when used alone. A site index may be low for several reasons. These reasons may not be the same in different environments and may or may not limit various land management techniques. Site index should be combined with other environmental information. For example, Hayes and Hallin (1962) rated the South Umpqua area for Douglas-fir, ponderosa pine, and sugar pine by using site indexes and elevation.

Classification of the vegetation into "communities" or "associations" delineated by measurements or estimates of plant composition, coverage, density, dominance, frequency, fidelity, etc., often is a useful way of comparing environments. If not carefully used, however, these community classifications tend to relate vegetation to vegetation rather than vegetation to environment. Moreover, vegetation is subject to historical influences in addition to environmental influences, and community classification is best done in undisturbed, stable areas--preferably by a community ecologist. The South Umpqua basin is a disturbed, unstable area, and most land managers are not community ecologists. Therefore, community classification is not employed in this environmental classification.

Fortunately, plants respond as individuals to the environments in which they live, and they may be used as environmental indicators without recourse to community classification (Gleason 1939, Goodall 1963). Rowe (1956) recommended using the presence or absence of plant species as easily interpreted indicators of environmental factors. Ideally, the environmental factors should be measured independently, then related to species' presence. Pluth and Arneman (1965) attempted this in Minnesota but used the botanical literature as their "measurements" and seem to have obtained

their results through a process of circular reasoning. Griffin (1967) actually measured one environmental factor (soil moisture) and related his indicator species to it. Several environmental factors were measured and related to species' presence by Waring and Major (1964) and by Waring (1969).

This classification of forest environments in the South Umpqua basin is based upon species' presence and the measurement or estimation of four environmental factors that are basic to plant growth: temperature, moisture, solar radiation, and soil type. It is applicable in that portion of the basin bounded on the west by North Myrtle, Canyon, and Starveout Creeks; on the south and east by the South Umpqua-Rogue divide; and on the north by the South Umpqua-Little River divide (fig. 1).

The classification presented here is a first step--a tool to be used in further work. Silvicultural prescriptions must be developed for each environment. This will be done by classifying environments before silvicultural treatment, recording success or failure of the treatment, then applying this information to all areas in the same environmental class. Eventually, a catalog of successful and unsuccessful treatments will be available for each environmental class in the South Umpqua basin.

METHODS

Fifty plots were established in the study area. Each plot consisted of a one-fifth-acre circle centered on one or more 6-foot conifer seedlings. All plots were in mature forest. All supported conifer regeneration, and none included topographic irregularities (gullies, ridge tops, slope changes, etc.). Forest type and understory vegetation were not considered, but the plots were carefully chosen to secure several plots on each aspect at elevations between 900 and 5,500 feet They were scattered throughout the study area, serving as references for measurements and observations and for comparisons of ecological parameters, plant species, and soils. One plot was logged before observation or measurement, so this classification of environments is based upon 49 plots.

The route to each plot and the plots themselves were plainly marked with plastic flagging to facilitate plot locations on dark nights. Elevations were determined with an altimeter calibrated against known bench marks, and aspects were determined with a compass. Slope percents were measured with an Abney hand level.

Summer soil temperature at 8 inches can be used as an index of environmental

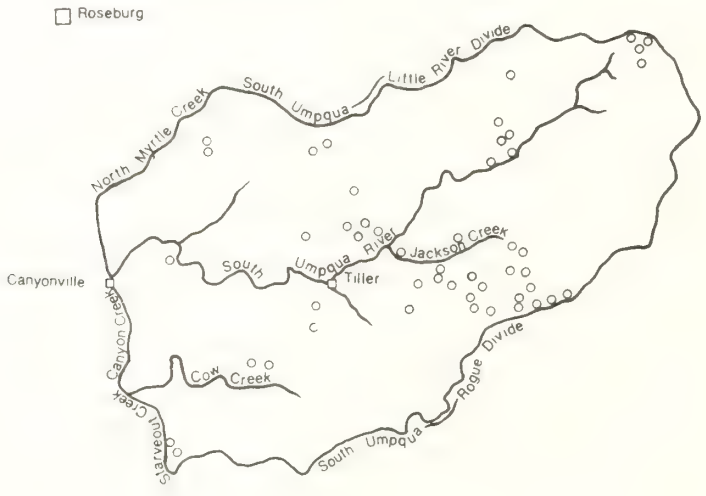

Figure 1.—The study area. Circles locate plots.

temperature (Shanks 1956). Soil temperatures were measured on 25 plots representative of all elevations and aspects. Maximum-minimum thermometer bulbs were buried 8 inches deep in covered pits during July 1970 and allowed to equilibrate for 2 weeks. The maximum and minimum soil temperatures recorded during August and September were then used to obtain a median soil temperature for each of the 25 plots. Animals and vandals damaged two of these plots, leaving 23 for measured temperature comparisons.

It should be emphasized that the median soil temperatures measured at 8 inches are crude measurements of summer temperatures. They do not indicate important differences in length of the growing season. Elevation was used as an independent, indirect indicator of growing season length.

Moisture conditions on each plot were measured by using the pressure bomb technique described by Waring and Cleary (1967). Between 10:00 p.m. and dawn, three or more twigs were clipped from each of the 6-foot conifer seedlings on each plot. Plant moisture stresses were immediately determined in each cut twig by measuring the gas pressure required to extrude sap from the cut end of the twig when its needles were gradually pressurized in the pressure bomb chamber. Sizable variations occasionally occurred on the same plot. These variations seemed to be caused by branch injuries or unhealthy conifer seedlings. (An injured branch or dying seedling is under high moisture stress even when it is growing in moist conditions.) Accordingly, the lowest moisture stress recorded on a plot at any given nocturnal visit was considered to be the best estimate of plant moisture stress at that time. When moisture stresses were measured first between 10:00 p.m. and midnight and then again just before dawn on the same plots, 2-atmosphere drops in plant moisture stresses were observed. Since it was physically impossible to visit all 49 plots just before dawn, even though the minimum moisture stress measured just before dawn best reflects soil moisture conditions, 2 atmospheres were subtracted from moisture stresses measured between 10:00 p.m. and midnight. One atmosphere was subtracted from moisture stresses measured between midnight and 2:00 a.m. No adjustments were made for moisture stresses measured after 2:00 a.m.

As moisture stress data accumulated, differences between conifer species became evident. Wherever grand fir and Douglas-fir seedlings occurred together, grand fir was under lower moisture stress. Since neither grand fir nor Douglas-fir seedlings occurred on all 49 plots, moisture stresses in 59 pairs of side-by-side grand fir and Douglas-fir seedlings were measured throughout the South Umpqua basin to compare moisture stresses in these species. A regression was calculated from the resulting data. All final moisture stress values were expressed in terms of grand fir moisture stress, using grand fir measurements where available and the regression wherever only Douglas-fir occurred. The grand fir moisture stresses, expressed in atmospheres, were used as indexes of moisture conditions on the plots.

Nocturnal moisture stresses were measured on every plot during the weeks of July 20, August 3, August 18, and September 8, 1969, until the autumn rains. The September moisture stresses were higher than those measured earlier in the season; they represented the peak of summer drought in 1969 and were subsequently used in all moisture comparisons.

Potential solar radiation was estimated for each plot by using measured slope and aspect to obtain a radiation index from the tables of Frank and Lee (1966). Table 1 lists these indexes for the South Umpqua area.

Soils were examined by digging a 3-foot pit on each plot during the spring of 1970. The soil profile was diagramed in each pit, and color, texture, density, stoniness, and pH were recorded for each horizon. Depth to bedrock, parent material, and rooting depth were also recorded wherever possible.

Plants growing on the plots were collected and identified weekly from April 1 to June 20, then biweekly from June 20 until September 1969. All vascular plant

Table 1.–Radiation indexes for the South Umpqua area, by aspect and slope[1]

Aspect	Percent slope										
	0	10	20	30	40	50	60	70	80	90	100
N.	0.465	0.426	0.386	0.345	0.306	0.272	0.244	0.219	0.198	0.179	0.163
S.	.465	.498	.527	.551	.569	.582	.591	.596	.599	.599	.597
NNE.-NNW.	.465	.429	.387	.355	.320	.288	.260	.237	.217	.199	.184
SSE.-SSW.	.465	.496	.523	.545	.562	.574	.582	.587	.589	.589	.588
NE.-NW.	.465	.438	.410	.383	.357	.334	.313	.295	.279	.266	.255
SE.-SW.	.465	.488	.509	.527	.540	.549	.556	.559	.560	.560	.558
ENE.-WNW.	.465	.450	.435	.421	.407	.395	.383	.373	.364	.355	.348
ESE.-WSW.	.465	.477	.489	.498	.505	.509	.512	.512	.511	.510	.507
E.-W.	.465	.464	.463	.461	.459	.456	.452	.449	.444	.440	.435

[1/] Calculated for lat. 43° N. from the tables of Frank and Lee (1966).

species present were identified.[1/] The species lists obtained from the 49 plots were compared with plot temperature and moisture data to estimate temperature and moisture ranges for every plant species. Those species with limited or characteristic ranges were used as indicators. The indicator species were weighted by assigning them point values in a procedure similar to that used by Rowe (1956). Those typical of warm or wet environments were weighted heavily. Those typical of cold or dry environments were weighted lightly. Point values used are as follows:

Temperature	Moisture
12 (hot)	15 (wet)
8	10
4	5
1 (cold)	1 (dry)

A plant temperature index for each plot was calculated by averaging the point values of all indicator species present on the plot. A plant moisture index was calculated similarly.

[1] *Taxonomists at the U.S. Forest Service Herbarium, Washington, D.C., identified many of the plants.*

RESULTS

ELEVATION

Plot elevations ranged from 910 feet to 5,440 feet. They were divided into three groups for classification purposes:

Elevation	Elevation class
Below 2,500 feet	Low elevation
2,500 to 4,000 feet	Middle elevation
Above 4,000 feet	High elevation

Of the 49 plots, 18 were at low elevations, 15 at middle elevations, and 16 at high elevations (table 2).

TEMPERATURE

Median summer soil temperatures at a depth of 8 inches ranged from a low of 48.0° F. recorded at an elevation of 5,180 feet to a high of 60.5° F. recorded at 2,220 feet (table 2). Aspect apparently was less important than elevation and cold air drainage in determining summer temperature, for both of these temperatures were recorded on southern aspects. Cold air drainage seemed to be particularly influential in determining summer soil temperatures.

Table 2.–Plot elevations, temperatures, moisture, aspects, slopes, radiation indexes, and soil series

Elevation class and plot elevation	Median soil temperature	Estimated temperature class[1/]	Plant moisture stress	Estimated moisture class[1/]	Aspect	Slope	Radiation index	Radiation class	Soil series
Feet	*° F.*		*Atmospheres*			*Percent*			
Low:									
1,520	60.0	Hot	19.3	Very dry	SE.	25	.509	Moderate	Prong
1,590	58.0	Hot	15.0	Dry	SSE.	80	.589	High	Coyote
1,460	59.5	Hot	13.5	Dry	WNW.	40	.407	Low	Prong
2,220	60.5	Hot	11.3	Moist	S.	30	.551	High	Freezeout
910	57.5	Warm	20.9	Very dry	NE.	85	.266	Low	Prong
2,430	55.5	Warm	17.1	Very dry	WNW.	50	.395	Low	Straight
1,720	—	Warm	15.0	Dry	S.	20	.527	High	Boze
1,890	56.5	Warm	13.6	Dry	SSW.	50	.574	High	Freezeout
2,160	--	Warm	14.5	Dry	SW.	40	.540	High	Bullock
1,750	—	Warm	14.1	Dry	ENE.	20	.435	Moderate	Tallow
2,280	--	Warm	8.2	Dry	ESE.	30	.498	Moderate	Fivesticks
1,300	56.5	Warm	7.0	Moist	S.	60	.591	High	Crater Lake
2,440	--	Warm	9.3	Moist	SSE.	20	.523	High	Dumont
2,060	55.5	Warm	6.0	Moist	SW.	10	.488	Moderate	Acker
1,650	--	Cool	3.3	Moist	Level	0	.465	Moderate	Alluvium
1,730	--	Cool	3.3	Moist	Level	0	.465	Moderate	Alluvium
2,210	--	Cool	4.7	Moist	WNW.	20	.435	Moderate	Prong
2,080	55.5	Cool	9.3	Moist	NE.	30	.383	Low	Acker
Middle:									
3,100	59.0	Hot	14.1	Dry	S.	35	.551	High	Prong
3,050	--	Warm	9.9	Dry	SW.	40	.540	High	Acker
3,140	—	Warm	8.7	Dry	SW.	45	.540	High	Deadman
2,870	--	Warm	12.3	Dry	N.	15	.426	Moderate	Bullock
3,080	—	Warm	14.7	Dry	SE.	20	.509	Moderate	Zinc
3,180	--	Warm	15.5	Dry	WSW.	40	.505	Moderate	Boze
2,660	56.0	Warm	8.3	Dry	ENE.	60	.383	Low	Acker
2,950	--	Warm	11.3	Moist	ESE.	30	.498	Moderate	Vena
2,620	56.5	Warm	4.7	Moist	ENE.	70	.373	Low	Straight
2,690	57.0	Cool	12.2	Dry	SSE.	40	.562	High	Deadman
3,390	--	Cool	4.7	Moist	ENE.	20	.435	Moderate	Acker
3,660	--	Cool	4.3	Moist	SW.	20	.509	Moderate	Boze
3,670	54.0	Cool	4.0	Moist	SE.	50	.549	High	Vena
3,860	54.0	Cool	4.3	Moist	NNW.	35	.355	Low	Prong
3,990	54.0	Cold	5.0	Moist	E.	40	.459	Moderate	Freezeout
High:									
4,100	--	Warm	9.9	Moist	SW.	40	.540	High	Bullock
4,040	54.5	Cool	6.7	Moist	SSE.	30	.545	High	Gustin
4,180	--	Cool	4.3	Moist	S.	20	.527	High	Acker
4,550	--	Cold	3.3	Moist	SSW.	25	.545	High	Prong
4,820	--	Cold	6.0	Moist	SW.	55	.549	High	Snowbird
4,870	53.0	Cold	3.7	Moist	SSW.	35	.545	High	Snowbird
5,260	--	Cold	5.7	Moist	SE.	30	.527	High	Vena
4,330	--	Cold	4.7	Moist	SE.	35	.527	High	Prong
4,070	—	Cold	8.3	Moist	ESE.	55	.509	Moderate	Prong
4,190	--	Cold	5.3	Moist	N.	15	.426	Moderate	Vena
5,180	48.0	Cold	4.7	Moist	SSE.	5	.465	Moderate	Freezeout
5,240	--	Cold	4.7	Moist	NW.	10	.438	Moderate	Prong
4,500	51.5	Cold	6.0	Moist	ENE.	50	.395	Low	Prong
4,300	51.1	Cold	8.0	Moist	ENE.	65	.373	Low	Hummingbird
5,060	--	Cold	2.7	Moist	NE.	20	.410	Low	Acker
5,440	50.0	Cold	5.0	Moist	NE.	25	.410	Low	Vena

1/ Estimates based upon presence of indicator plants.

Plant indicator species found to be useful in estimating summer soil temperatures are listed in table 3. When the plant temperature indexes calculated by using these indicator species were plotted against the measured soil temperatures for each of the 23 temperature plots (fig. 2), the correlation was highly significant (r = 0.94).

Table 3.–Species and point values used in calculating plant temperature indexes

Species[1/]	Point value	Species[1/]	Point value
Abies magnifica Murr. var. *shastensis* Lemm.	1	*Ligusticum apiifolium* (Nutt.) Gray	4
Actaea rubra (Ait.) Willd.	1	*Lonicera hispidula* Dougl.	12
Anemone deltoidea Hook.	4	*Montia sibirica* (L.) How.	4
Arbutus menziesii Pursh	8	*Pachystima myrsinites* (Pursh) Raf.	4
Arctostaphylos canescens Eastw.	4	*Pinus ponderosa* Dougl.	4
Arnica cordifolia Hook.	4	*Pyrola picta* J. E. Sm.	4
Berberis aquifolium Pursh	12	*Quercus chrysolepis* Liebm.	8
Cornus nuttallii Aud.	4	*Quercus kelloggii* Newb.	8
Cynoglossum grande Lehm.	8	*Rhus diversiloba* T. & G.	12
Disporum hookeri (Torr.) Britt.	4	*Satureja douglasii* (Benth.) Brig.	12
Festuca californica Vas.	8	*Taxus brevifolia* Nutt.	4
Galium oreganum Britt.	1	*Thuja plicata* D. Don	4
Gaultheria shallon Pursh	12	*Tiarella unifoliata* Hook.	1
Goodyera oblongifolia Raf.	4	*Tsuga heterophylla* (Raf.) Sarg.	4
Habenaria unalascensis (Spreng.) Wats.	4	*Valeriana sitchensis* Bong.	1
		Xerophyllum tenax (Pursh) Nutt.	4

[1/] Nomenclature follows Hitchcock et al. (1955-69) and Peck (1961).

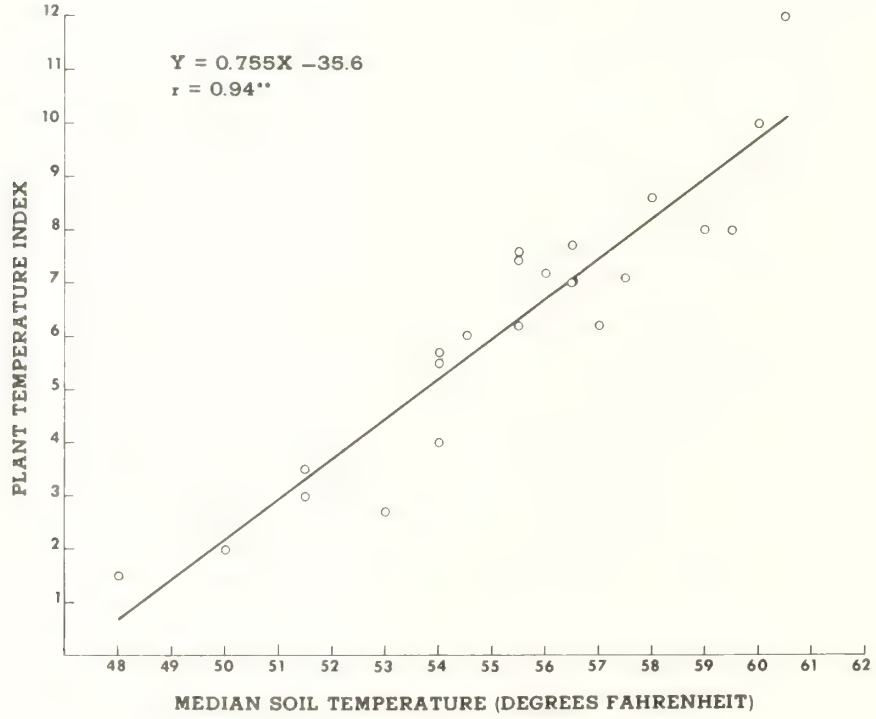

Figure 2.—Correlation of median August-September soil temperature at 8 inches and plant temperature index.

To facilitate classification, the range in plant temperature indexes was divided into four groups:

Plant temperature index	Temperature class
8.0 and above	Hot
6.5 to 7.9	Warm
4.1 to 6.4	Cool
4.0 and below	Cold

Five of the 49 plots were classified "hot," 19 were "warm," 11 were "cool," and 14 were "cold."

MOISTURE

The moisture stress regression for grand fir-Douglas-fir is shown in figure 3. All plant moisture stresses were measured in pounds per square inch, expressed in terms of grand fir stress, and converted to atmospheres (1 atmosphere equals 14.7 pounds per square inch). The nocturnal plant moisture stresses measured in September 1969 ranged from a low of 2.7 atmospheres to a high of 20.9 atmospheres (table 2). Plant indicator species found to be useful in estimating moisture stress are listed in table 4. When the plant moisture indexes calculated by using these indicator species were plotted against the measured moisture stresses on each plot (fig. 4), the correlation was highly significant ($r = 0.90$).

The range in plant moisture indexes was divided into three groups:

Plant moisture index	Moisture class
Above 8.0	Moist
4.0 to 8.0	Dry
Below 4.0	Very dry

Of the 49 plots, 31 were classified "moist," 15 were "dry," and only three were "very dry."

POTENTIAL SOLAR RADIATION

Calculated radiation indexes on the 49 plots ranged from 0.266 (85-percent slope on a NE. aspect) to 0.591 (60-percent slope on a S. aspect). This range in potential solar radiation was divided into three groups:

Radiation index	Radiation class
Below 0.420	Low
0.420 to 0.520	Moderate
Above 0.520	High

Table 4.–Species and point values used in calculating plant moisture indexes

Species[1/]	Point value	Species[1/]	Point value
Adenocaulon bicolor Hook.	10	*Gaultheria shallon* Pursh	10
Amelanchier alnifolia var. *humptulipensis* (G. H. Jones) C. L. Hitchc.	10	*Lonicera hispidula* Dougl.	1
Anemone deltoidea Hook.	15	*Osmorhiza chilensis* (Hook.) Am.	10
Arctostaphylos canescens Eastw.	10	*Pinus ponderosa* Dougl.	5
Arnica cordifolia Hook.	10	*Psoralea physodes* Hook.	10
Berberis aquifolium Pursh	5	*Pyrola picta* J. E. Sm.	10
Berberis nervosa Pursh	10	*Rhododendron macrophyllum* G. Don	15
Castanopsis chrysophylla (Dougl.) A. DC.	10	*Rhus diversiloba* T. & G.	1
Cephalozia bicuspidata H. & A.	10	*Rubus nivalis* Dougl.	15
Clintonia uniflora (Schult.) Kunth	15	*Smilacina stellata* (L.) Desf.	15
Corallorhiza maculata Raf.	10	*Thuja plicata* D. Don	15
Cornus nuttallii Aud.	10	*Tsuga heterophylla* (Raf.) Sarg.	15
Festuca californica Vasey	5	*Vaccinium parvifolium* J. E. Sm.	10

[1/] Nomenclature follows Hitchcock et al. (1955-69) and Peck (1961).

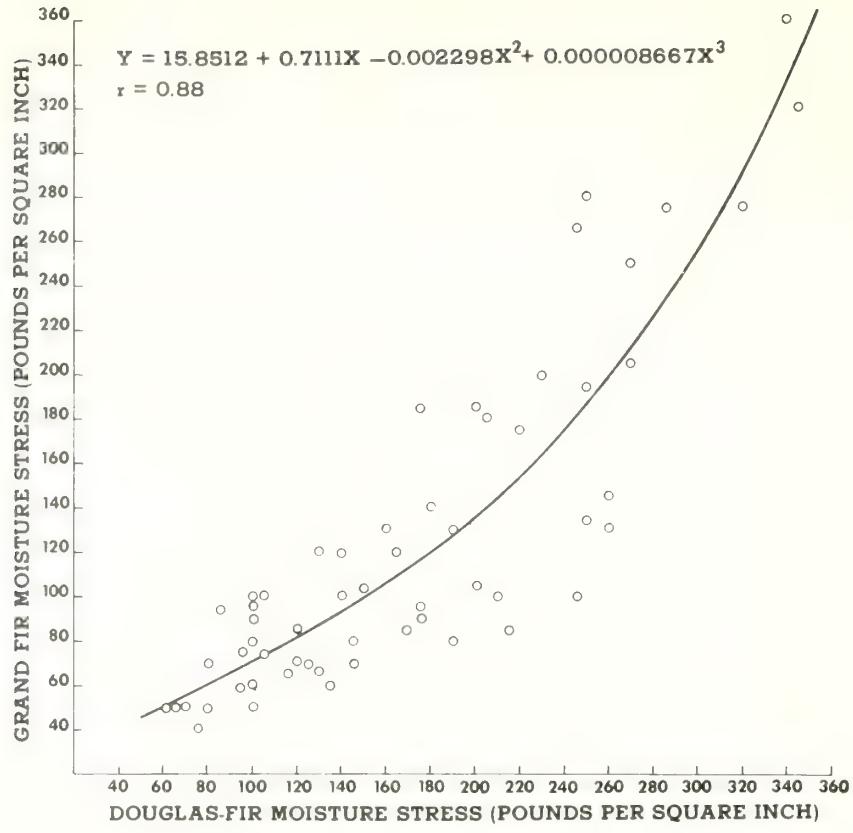
Y = 15.8512 + 0.7111X −0.002298X²+ 0.000008667X³
r = 0.88
GRAND FIR MOISTURE STRESS (POUNDS PER SQUARE INCH)
DOUGLAS-FIR MOISTURE STRESS (POUNDS PER SQUARE INCH)

Figure 3.—Moisture stress regression for grand fir-Douglas-fir.

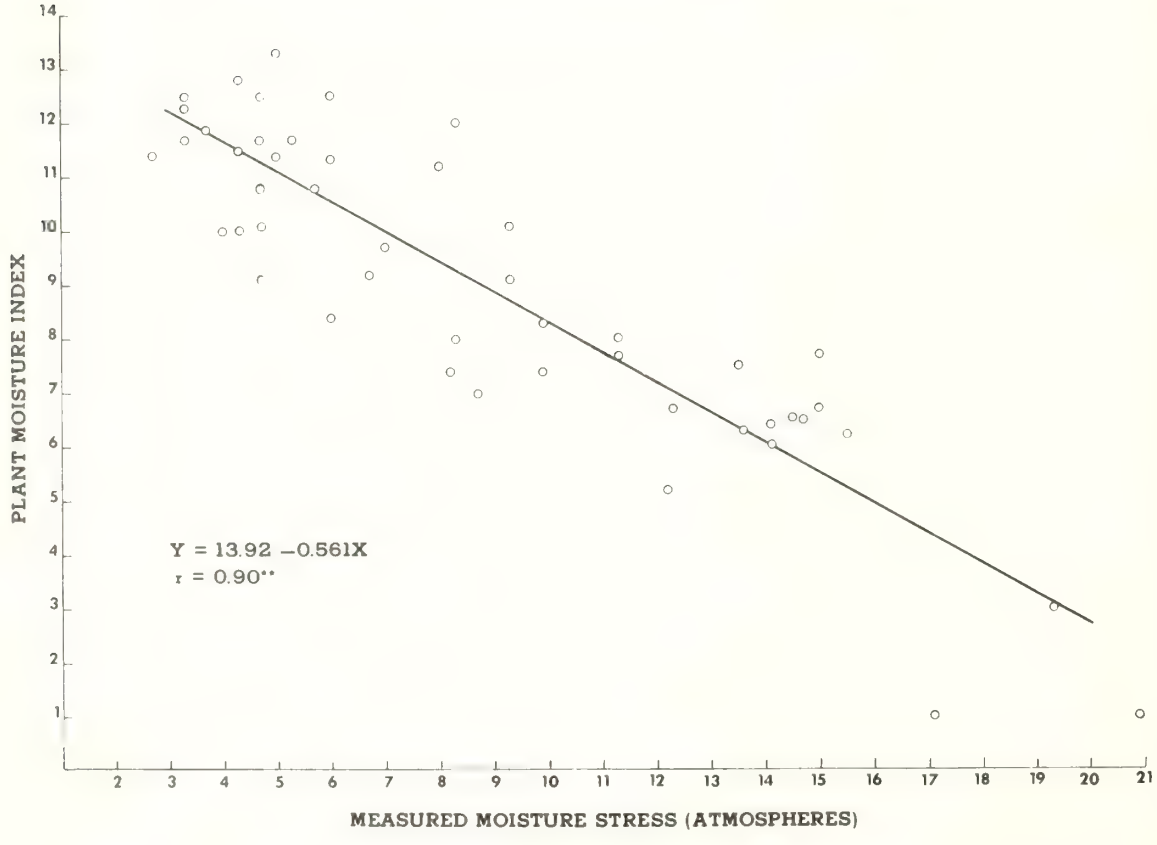

Figure 4.—Correlation of measured moisture stress and plant moisture index.

Eleven plots were classified "low radiation," 18 were "moderate radiation," and 20 were "high radiation" environments.

SOILS

Profile diagrams and descriptions differed from plot to plot, but no single soil measurement or observation was deemed reliable enough to be useful in comparing the wide variety of soils found in the South Umpqua basin. The soil profile description for each plot was therefore compared with the soil series descriptions included in the South Umpqua Soil Survey.[2] Unfortunately, this soil survey covered only part of the study area--that part north and east of Jackson Creek. Nevertheless, the soil survey series descriptions matched plot soil profile descriptions well enough to permit tentative classification of the soils on all 49 plots into named soil series.

Since complete soil series descriptions are rather long and often not readily available, a simplified soil series key was constructed from soil survey series descriptions and field observations of the plot soils. This soils key (appendix IV) includes 18 series. No claim is made to absolute accuracy, and unerring soil series identification is not guaranteed when the key is used. Nevertheless, it is a simple, usable field key that should permit field classification of South Umpqua soils into easily recognizable, comparable categories.

DISCUSSION

Five environmental factors were classified in the South Umpqua basin: elevation (three classes), temperature (four classes), moisture (three classes), potential solar radiation (three classes), and soil (18 series). If all classes for all five factors are considered, in all possible combinations, almost 2,000 environmental categories are possible. A simple ordering of classification categories is essential if meaningful area comparisons are to be accomplished.

[2] *USDA Forest Service unpublished inservice report, 1961.*

Elevation, temperature, and moisture should be considered first when classifying and comparing environments. Elevation is easily obtained from a topographic map. Temperature and moisture classes can be quickly determined in the field by using indicator plants to calculate temperature and moisture indexes. In many instances, no further classification will be necessary. For example, similarities and differences between a low-elevation, warm, moist environment and a low-elevation, hot, dry environment will be obvious.

If more information is desired, potential solar radiation and soil series may be determined. A low-elevation, warm, moist, high-radiation environment with Bullock soil certainly differs from a low-elevation, warm, moist, moderate-radiation environment with Acker soil. For some purposes, the radiation and soil differences may not be important; for others, they may be essential.

Descriptive phrases seem to constitute the best environmental labels. Elevation (low, middle, or high), temperature (cold, cool, warm, or hot), moisture (moist, dry, or very dry), solar radiation (low, moderate, or high), and soil (series name) should be stated in that order. For example, the environments of two plots listed in table 2 are described as follows:

First plot = low-elevation, hot, very dry, moderate-radiation environment with Prong soil

Last plot = high-elevation, cold, moist, low-radiation environment with Vena soil

Abbreviations may be used where space is limited, as on maps:

First plot = L, Ht, Vd, m - Pr

Last plot = H, Cd, Mt, l - Ve.

The information required to relate this environmental classification to land management techniques will not be available until the techniques are used and evaluated in classified environments. However, some productivity relationships are already apparent. Douglas-fir site trees were measured on 44 of the 49 plots, and site classes were approximated by using McArdle and Meyer's (1930) site curves.

These curves for northwestern Oregon and Washington probably do not accurately portray South Umpqua growth patterns, but no better ones are available. When the approximate site classes were compared with environmental data, the following relationships were evident:

1. The Acker, Alluvium, Coyote, and Freezeout series are good Douglas-fir soils.

2. The Bullock, Fivesticks, Gustin, Tallow, and Zinc series are poor Douglas-fir soils. As Stephens (1965) observed, ponderosa pine grows better than Douglas-fir on soils like these which have clay subsoils.

3. Cool, moist environments are good Douglas-fir sites wherever deep, nonsticky soils occur.

4. Environments with plant temperature indexes below 2.5 or with plant moisture indexes below 7.0 are poor Douglas-fir sites.

Several plant species were found to be useful indicators of Douglas-fir site (table 5). When the indexes calculated by using these indicator species were plotted against McArdle-Meyer site indexes on each plot (fig. 5), the correlation was highly significant ($r = 0.87$).

Table 5.–Species and point values used in calculating plant site indexes

Species[1/]	Point value	Species[1/]	Point value
Abies magnifica Murr. var. *shastensis* Lemm.	1	*Montia sibirica* (L.) How.	10
Acer circinatum Pursh	10	*Oxalis* sp.	10
Arctostaphylos canescens Eastw.	1	*Pachystima myrsinites* (Pursh) Raf.	1
Arctostaphylos nevadensis Gray	1	*Pinus ponderosa* Dougl.	1
Asarum hartwegii Wats.	10	*Quercus chrysolepis* Liebm.	1
Berberis aquifolium Pursh	1	*Quercus garryana* Dougl.	1
Campanula scouleri Hook.	10	*Rhus diversiloba* T. & G.	1
Castanopsis chrysophylla (Dougl.) A. DC.	5	*Rubus nivalis* Dougl.	1
Ceanothus integerrimus H. & A.	10	*Salix* sp.	1
Cynoglossum grande Lehm.	5	*Smilacina racemosa* (L.) Desf.	1
Disporum hookeri (Torr.) Britt.	5	*Smilacina stellata* (L.) Desf.	10
Festuca californica Vasey	5	*Taxus brevifolia* Nutt.	1
Galium oreganum Britt.	1	*Thuja plicata* D. Don	10
Ligusticum apiifolium (Nutt.) Gray	1	*Trillium ovatum* Pursh	10
		Tsuga heterophylla (Raf.) Sarg.	5
		Vaccinium membranaceum Dougl.	10

[1/] Nomenclature follows Hitchcock et al. (1955-69) and Peck (1961).

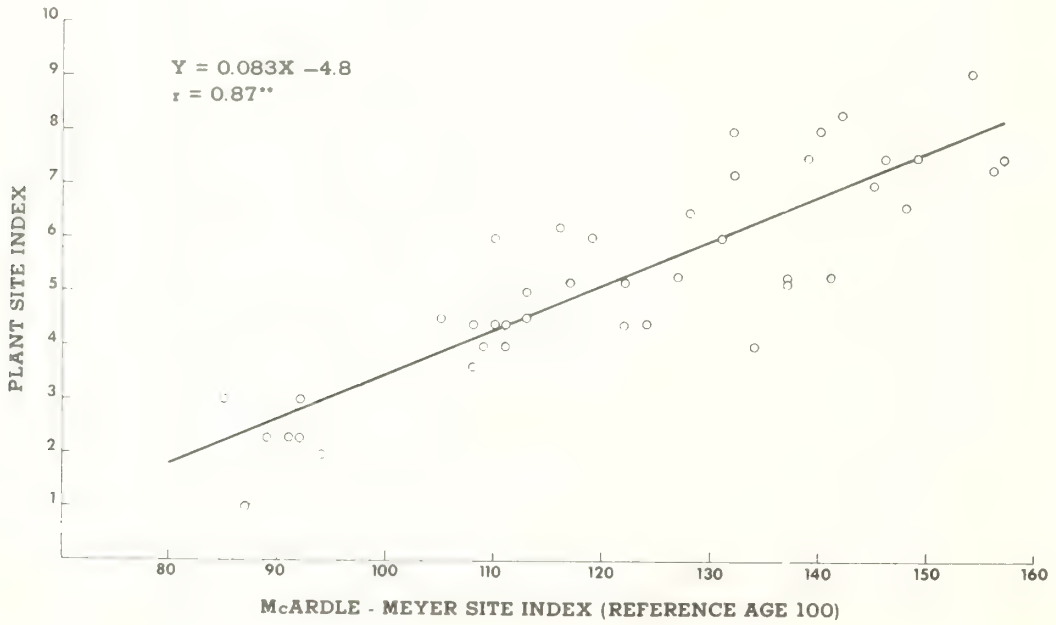

Figure 5.—Correlation of McArdle-Meyer site index and plant site index.

Photographs of the indicator plants and an outline of classification procedure are included in the appendixes. These appendixes have one primary purpose--field use. If used in the field, the procedure outlined on these pages should provide comparisons that will eventually make it possible to categorize environments in terms of specific land management techniques.

Users are cautioned that this classification is applicable only to mature stands in the study area. It is not appropriate for recently logged stands and should not be used outside the South Umpqua basin.

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APPENDIX I

INDICATOR PLANT SPECIES

Most land managers are familiar with the following indicator plants. They have not been photographed.

Abies magnifica var. *shastensis* (Shasta red fir)

Acer circinatum (vine maple)

Arbutus menziesii (madrone)

Castanopsis chrysophylla (chinquapin)

Cornus nuttallii (western flowering dogwood)

Gaultheria shallon (salal)

Pinus ponderosa (ponderosa pine)

Rhododendron macrophyllum (western rhododendron)

Rhus diversiloba (poison oak)

Salix sp. (willow)

Taxus brevifolia (western yew)

Thuja plicata (western redcedar)

Tsuga heterophylla (western hemlock)

Xerophyllum tenax (beargrass)

Another, less familiar, indicator plant was not photographed: *Festuca californica* (California fescue) is a large grass. Its 3- to 5-foot-tall flowering stems grow in clusters and bear few leaves. They support loose, open, drooping groups of short-awned flowers. The densely clumped basal leaves are stiff and rough, often fold inward upon themselves.

Actaea rubra (western baneberry).—Compound leaves are in groups of three. The leaflets are tipped with tiny, blunt spines. Flowers are white, berries red.

Adenocaulon bicolor (trail plant).—Leaves are dark green and smooth above, silvery and white-woolly below. Flowers are small, white, and inconspicuous.

Amelanchier alnifolia (western serviceberry).—A large shrub or small tree. The thin leaves are simple, with sharply toothed apical halves. Flowers are white, berries purple.

Anemone deltoidea (western white anemone).—Basal leaves are trifoliate, with toothed or incised margins. Stem leaves are borne in a whorl below the large white flower.

Arctostaphylos canescens (hoary manzanita).—An upright shrub with smooth, wine-red bark. Leaves are gray-green and finely gray-woolly, with short-toothed tips. Flowers are white or pink.

Arctostaphylos nevadensis (pine mat manzanita).—A prostrate shrub. Leaves are bright green with short-toothed tips. Flowers are white or pink.

Arnica cordifolia (heart-leaved arnica).—The large leaves are opposite and broad, borne in pairs on the flowering stem. The daisy-like flower is yellow.

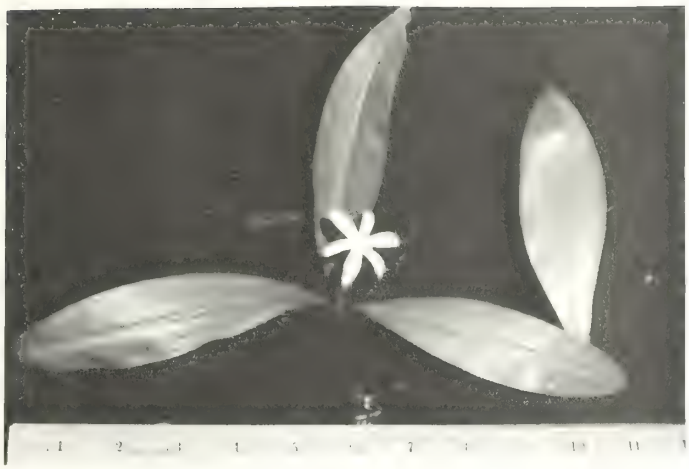
Asarum hartwegii (marbled wild ginger).—Large leaves are conspicuously white-mottled or marbled above. Flowers are brownish purple, inconspicuous, borne very near the ground.

Berberis aquifolium (Oregon grape).—Compound leaves are glossy above, with only five to seven leaflets. Flowers are yellow, berries deep blue.

Berberis nervosa (long-leaved Oregon grape).—Compound leaves are dull above, with nine to 15 leaflets. Flowers are yellow, berries deep blue.

Campanula scouleri (Scouler's harebell).—Leaves and stems have milky juice. Flowers are pale blue or white.

Ceanothus integerrimus (deerbrush).—An upright shrub with slender, flexible twigs. The small, smooth-margined, alternate leaves usually are three-veined at the base. Flowers are white or blue.



Clintonia uniflora (queencup).—Leaves are flat and thin, with parallel veins and slightly hairy margins. The flower is white, the berry deep blue.

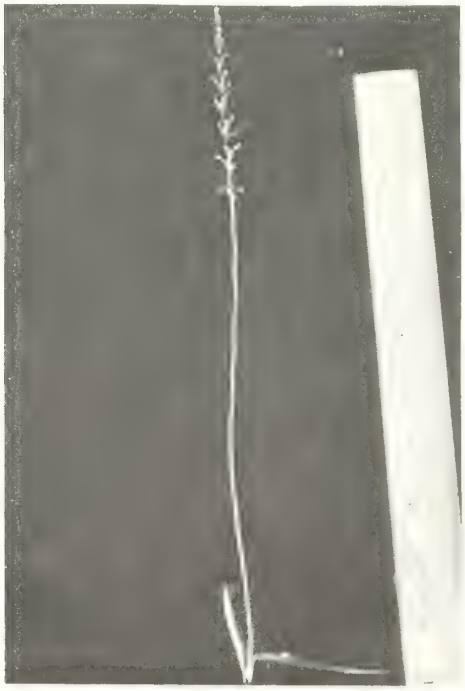
Corallorhiza maculata (spotted coralroot).—The brownish-purple stem is leafless. Orchidlike flowers have white lips that are mottled with dark red.

Cynoglossum grande (great houndstongue).—The large, alternate leaves are woolly below, with long petioles. Flowers are blue and white.

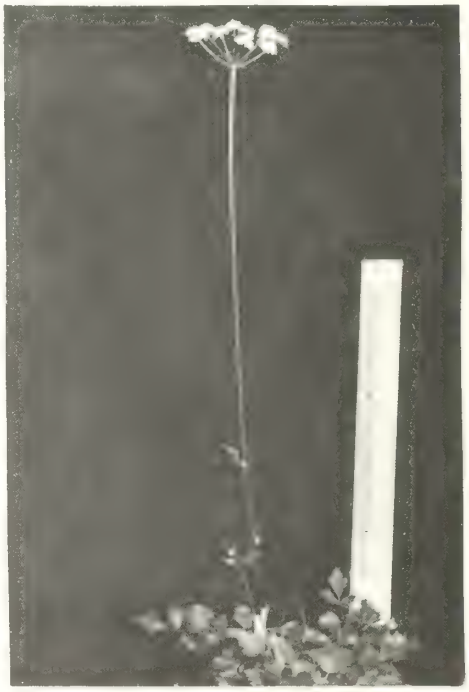
Disporum hookeri (Hooker's fairybells).—Alternate, sessile leaves are borne on a branched stem. Flowers are greenish white, berries red.

Galium oreganum (Oregon bedstraw).—Conspicuously three-veined leaves are borne in whorls of four. Flowers are tiny, yellowish green.

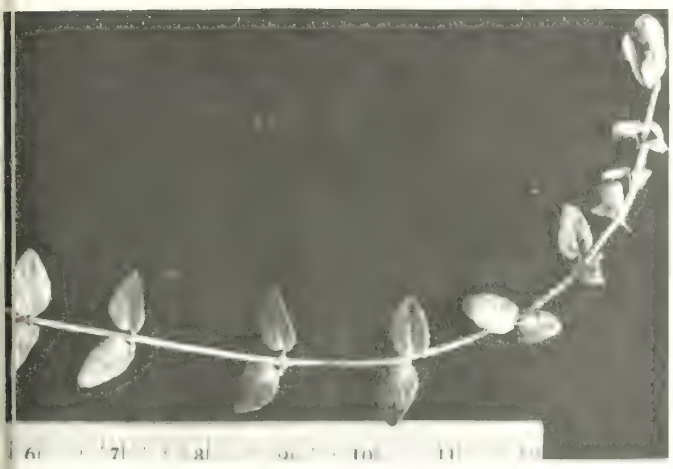
Goodyera oblongifolia (rattlesnake plantain).—Thick, dark green leaves are conspicuously veined and mottled with white. The flowering spike is greenish white.



Habenaria unalascensis (short-spurred rein orchid).—Leaves somewhat resemble those of *Clintonia* in early spring, but they are distinctly lined below and have hairless margins. Later, when the greenish spike of spurred flowers appears, the leaves wither.



Ligusticum apiifolium (parsley-leaved lovage).—Compound basal leaves are cleft and dissected. The small, white flowers are clustered in umbels.



Lonicera hispidula (hairy honeysuckle).—A vine or climbing shrub with hairy, opposite leaves. It seldom blooms.

Montia sibirica (miner's lettuce).—Basal leaves long-petioled, stem leaves sessile. Flowers white or pink with rose-colored stripes and notched petals.

Osmorhiza chilensis (western sweet cicely).—Leaves are compound, each consisting of groups of three leaflets. The flowers are tiny, greenish white.

Oxalis sp. (oxalis).—Leaves are cloverlike.

Pachystima myrsinites (Oregon boxwood).—A low shrub with glossy, tooth-margined leaves. Flowers are green and red, very small and inconspicuous.

Psoralea physodes (California tea).—A shrubby herb with leaves in threes. Flowers are dull greenish white.

Pyrola picta (white-veined wintergreen).—The dark green, dull leaves are marbled with white along the veins above. They are unmarbled and often purple-tinged below. Flowers are yellowish- or greenish-white.

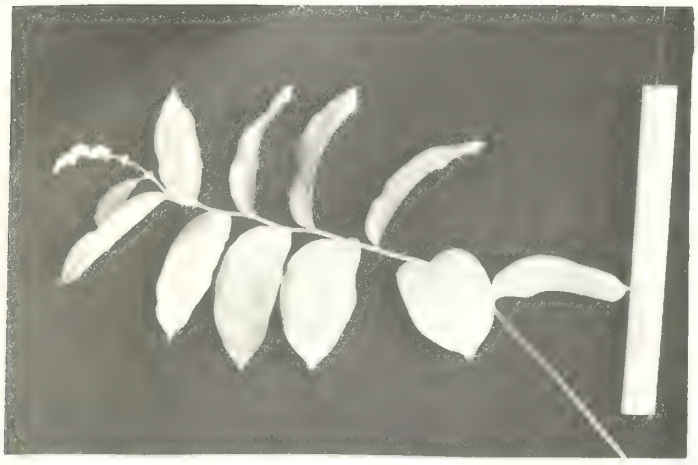
Quercus chrysolepis (canyon oak).—An often shrubby tree. The evergreen leaves are rigid and spiny (as shown) or rigid and smooth-margined. Both leaf types often occur on the same tree.

Quercus garryana (Oregon oak).—Leaf margins are rounded and without bristles.

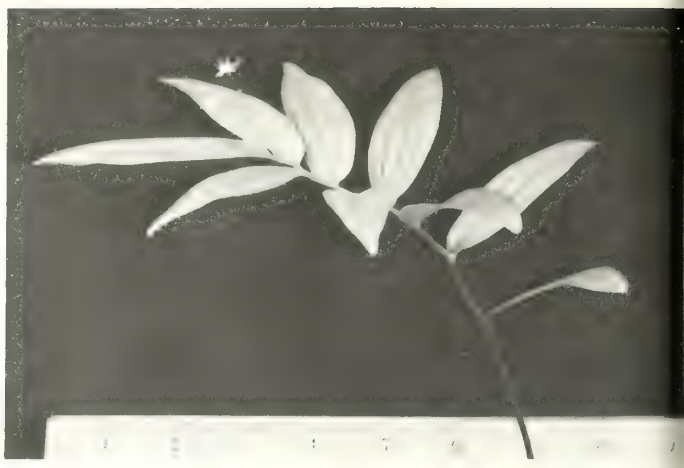
Quercus kelloggii (California black oak).—Leaf margins are bristle-tipped.

Rubus nivalis (snow bramble).—A trailing vine with very glossy leaves and curved prickles. Flowers are dull purple, inconspicuous.

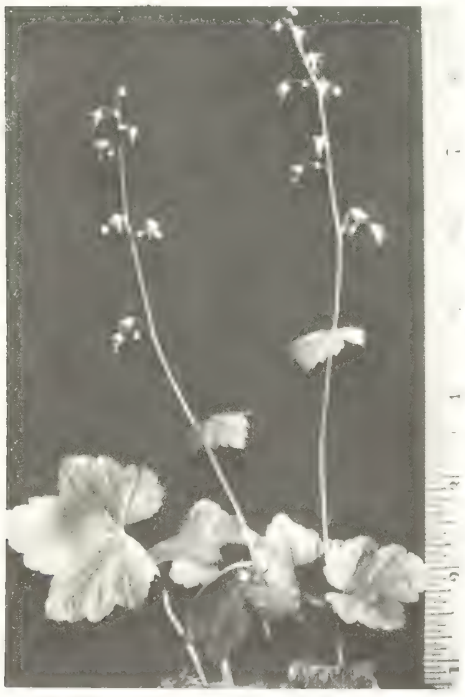
Satureja douglasii (yerba buena).—A prostrate herb with slender, trailing stems. The leaves have a strong, medicinal odor when crushed. Flowers are white or pink.



Smilacina racemosa (false Solomon's seal).—The unbranched stem is quite large. Numerous white flowers are borne in a dense terminal cluster.



Smilacina stellata (few-flowered false Solomon's seal).—The unbranched stem is quite small. A few white flowers are borne in a loose terminal group.



Tiarella unifoliata (western coolwort).—Leaves are simple, three- to five-lobed. Flowers are white.

Trillium ovatum (western trillium).—Leaves are borne in a whorl of three. The flower is white, turns purplish red with age.

Vaccinium membranaceum (thin-leaved huckleberry).—A shrub. The leaf margins are very finely toothed. Flowers are greenish white, berries purplish black.

Vaccinium parvifolium (red huckleberry).—A shrub. The green branches are sharply angled. Leaves have smooth margins. Flowers are pink, berries bright red.

Valeriana sitchensis (northern valerian).—Leaves are compound, opposite, and wavy-margined. Stems are hollow. Flowers are white or pink.

APPENDIX II

CLASSIFICATION PROCEDURE

I. Determine elevation class:

Below 2,500 feet = low elevation
2,500 to 4,000 feet = middle elevation
Above 4,000 feet = high elevation

II. Determine temperature and moisture classes:

A. Record the presence of all indicator plants by circling their point values on the tally sheet (Appendix III).

B. Calculate a temperature index by averaging the circled temperature values, then use this index to determine the temperature class:

8.0 and above = hot
6.5 to 7.9 = warm
4.1 to 6.4 = cool
4.0 and below = cold

C. Calculate a moisture index by averaging the circled moisture values, then use this index to determine the moisture class:

Above 8.0 = moist
4.0 to 8.0 = dry
Below 4.0 = very dry

III. Determine potential solar radiation class:

A. Measure slope and aspect with hand level and compass.

B. Look up the radiation index in table 1, then use this index to determine the radiation class:

Below 0.420 = low
0.420 to 0.520 = moderate
Above 0.520 = high

IV. Dig one or more soil pits at least 3 feet deep and determine soil series with the key in Appendix IV.

V. Describe the environment in a single phrase or series of abbreviations.

Example: Middle-elevation, warm, dry, high-radiation environment with Coyote soil (M, Wm, Dy, h - Co).

APPENDIX III

VEGETATION TALLY SHEET

Vegetation tally sheet for determining South Umpqua temperature and moisture indexes. To use, circle the values opposite each species present.

Species [1]	Temperature value	Moisture value
Abies magnifica var. *shastensis* (Shasta red fir)	1	--
Actaea rubra (western baneberry)	1	--
Adenocaulon bicolor (trail plant)	--	10
Amelanchier alnifolia (western serviceberry)	--	10
Anemone deltoidea (western white anemone)	4	15
Arbutus menziesii (madrone)	8	--
Arctostaphylos canescens (hoary manzanita)	4	10
Arnica cordifolia (heart-leaved arnica)	4	10
Berberis aquifolium (Oregon grape)	12	5
Berberis nervosa (long-leaved Oregon grape)	--	10
Castanopsis chrysophylla (chinquapin)	--	10
Ceanothus integerrimus (deerbrush)	--	10
Clintonia uniflora (queencup)	--	15
Corallorhiza maculata (spotted coralroot)	--	10
Cornus nuttallii (western flowering dogwood)	4	10
Cynoglossum grande (great houndstongue)	8	--
Disporum hookeri (Hooker's fairybells)	4	--
Festuca californica (California fescue)	8	5
Galium oreganum (Oregon bedstraw)	1	--
Gaultheria shallon (salal)	12	10
Goodyera oblongifolia (rattlesnake plantain)	4	--
Habenaria unalascensis (short-spurred rein orchid)	4	--
Ligusticum apiifolium (parsley-leaved lovage)	4	--
Lonicera hispidula (hairy honeysuckle)	12	1
Montia sibirica (miner's lettuce)	4	--
Osmorhiza chilensis (western sweet cicely)	--	10
Pachystima myrsinites (Oregon boxwood)	4	--
Pinus ponderosa (ponderosa pine)	4	5
Psoralea physodes (California tea)	--	10
Pyrola picta (white-veined wintergreen)	4	10
Quercus chrysolepis (canyon oak)	8	--
Quercus kelloggii (California black oak)	8	--
Rhododendron macrophyllum (western rhododendron)	--	15
Rhus diversiloba (poison oak)	12	1
Rubus nivalis (snow bramble)	--	15
Satureja douglasii (yerba buena)	12	--
Smilacina stellata (few-flowered false Solomon's seal)	--	15
Taxus brevifolia (western yew)	4	--
Thuja plicata (western redcedar)	4	15
Tiarella unifoliata (western coolwort)	1	--
Tsuga heterophylla (western hemlock)	4	15
Vaccinium parvifolium (red huckleberry)	--	10
Valeriana sitchensis (northern valerian)	1	--
Xerophyllum tenax (beargrass)	4	--

[1] Nomenclature follows Hitchcock et al. (1955-69) and Peck (1961).

	Temperature value	Moisture value
Total, circled values	_____	_____
Number of species circled	_____	_____
Index*	_____	_____

$$*\text{Index} = \frac{\text{Total circled values}}{\text{Number of species circled}}$$

FOR TEMPERATURE:

Index	Class
8.0 and above	Hot
6.5 to 7.9	Warm
4.1 to 6.4	Cool
4.0 and below	Cold

FOR MOISTURE:

Index	Class
Above 8.0	Moist
4.0 to 8.0	Dry
Below 4.0	Very dry

APPENDIX IV

FIELD KEY TO SOUTH UMPQUA SOIL SERIES

This key is based on field observations and the soil series descriptions listed in an unpublished inservice report of the South Umpqua Soil Survey, USDA Forest Service, 1961.

1. Red or reddish brown throughout profile 2
1. Not red or reddish brown throughout 5

2. Shallow, with many stones in top 2 feet and stone content increasing with depth 3
2. Deep, with very few stones in top 2 feet or with stone content decreasing with depth 4

3. Gravelly clay loam subsoil, sticky when wet . . . . . Coyote Series
3. Gravelly loam subsoil, not sticky . . . . . Straight Series

4. Clay subsoil . . . . . Dumont Series
4. Clay loam subsoil . . . . . Freezeout Series

5. Top 18 inches of profile uniformly very dark brown or black and homogeneous. Above 3,000 feet 6
5. Top 18 inches of profile not uniformly very dark brown or black 7

6. Entire profile very dark brown or black. Top 18 inches of profile stony . . . . . Hummingbird Series
6. Lower profile yellowish brown. Top 18 inches of profile not stony . . . . . Snowbird Series

7. Clay loam or clay subsoil, usually sticky 14
7. Loam or sand subsoil, seldom sticky 8

8. Flourlike pumice throughout profile. No gravel or stones . . . . . Crater Lake Series
8. Not flourlike, gravel or stones present 9

9. Gravelly, but without stones larger than 3 inches in diameter. Stream bottoms, stream terraces, and alluvial fans . . . . . Alluvium
9. Gravel absent or stones larger than 3 inches in diameter present 10

10. Shallow, with many stones in top 2 feet and stone content increasing with depth 12
10. Deep, with very few stones in top 2 feet or with stone content decreasing with depth 11

11. Soft, loose subsoil. Dark-colored parent rocks . . . . . Boze Series
11. Slightly hard, coherent subsoil. Light-colored parent rocks . . . . . Acker Series

12. Subsoil greenish or olive brown. Parent rocks green ..... Deadman Series
12. Subsoil brown, yellowish brown, or grayish brown 13

13. Yellowish brown subsoil. Dark-colored parent rocks ..... Prong Series
13. Brown or grayish brown subsoil. Light-colored parent rocks ..... Vena Series

14. Shallow, with many stones in top 2 feet and stone content increasing with depth. Clay loam subsoil ..... Deadman Series
14. Deep, with very few stones in top 2 feet or with stone content decreasing with depth. Sticky clay subsoil 15

15. Subsoil mottled 16
15. Subsoil not mottled 18

16. Mottling above shallowest sticky clay horizon ..... Tallow Series
16. Mottling within sticky clay horizon, not above 17

17. Top 6 inches of clay horizon grayish brown mottled with dark brown. Light-colored parent rocks ..... Gustin Series
17. Top 6 inches of clay horizon light olive brown, unmottled (mottling is lower in horizon). Dark-colored parent rocks ..... Zinc Series

18. Light olive brown to greenish brown clay horizon. Parent rocks green ..... Fivesticks Series
18. Brown to dark brown clay horizon. Parent rocks dark-colored but not green ..... Bullock Series

☆GPO—795-653

Minore, Don

1972. A classification of forest environments in the South Umpqua basin. USDA Forest Serv. Res. Pap. PNW-129, 28 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

A classification of forest environments by elevation, temperature, moisture, potential solar radiation, and soil type is described. It facilitates comparisons of forested areas--comparisons that eventually should make it possible to prescribe optimal management practices for every forest environment in the South Umpqua basin.

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Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

College, Alaska	Portland, Oregon
Juneau, Alaska	Roseburg, Oregon
Bend, Oregon	Olympia, Washington
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1972
USDA FOREST SERVICE RESEARCH PAPER PNW-130

LEVELS-OF-GROWING-STOCK COOPERATIVE STUDY ON DOUGLAS-FIR

REPORT NO. 2

THE HOSKINS STUDY, 1963-1970

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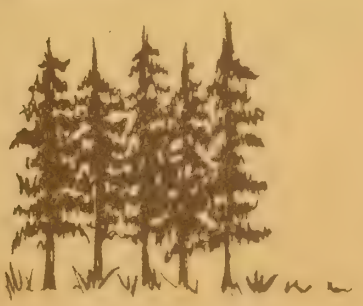

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
PORTLAND, OREGON

Levels-of-growing-stock study treatment schedule, showing percent of gross basal area increment of control plot to be retained in growing stock

Thinning	Treatment							
	1	2	3	4	5	6	7	8
	- - - - - - - - - - *Percent* - - - - - - - - - -							
First	10	10	30	30	50	50	70	70
Second	10	20	30	40	50	40	70	60
Third	10	30	30	50	50	30	70	50
Fourth	10	40	30	60	50	20	70	40
Fifth	10	50	30	70	50	10	70	30

Abstract for Report No. 1

Public and private agencies are cooperating in a study of eight thinning regimes in young Douglas-fir stands. Regimes differ in the amount of basal area allowed to accrue in growing stock at each successive thinning. All regimes start with a common level-of-growing-stock which is established by a conditioning thinning.

Thinning interval is controlled by height growth of crop trees, and a single type of thinning is prescribed.

Nine study areas, each involving three completely random replications of each thinning regime and an unthinned control, have been established in western Oregon and Washington, U.S.A., and Vancouver Island, Canada. Site quality of these areas varies from I through IV.

Climatic and soil characteristics for each area and data for the stand after the conditioning thinning are described briefly.

Keywords: Thinnings, stand growth, Douglas-fir, forest improvement cutting.

LEVELS-OF-GROWING-STOCK

COOPERATIVE STUDY

ON DOUGLAS-FIR

Report No. 2--The Hoskins Study, 1963-1970

by

John F. Bell, Associate Professor
School of Forestry, Oregon State University

and

Alan B. Berg, Professor
School of Forestry, Oregon State University

USDA Forest Service Research Paper PNW-130

Pacific Northwest Forest and Range Experiment Station
Forest Service Portland, Oregon
U.S. Department of Agriculture 1972

Study area	*Cooperator*
Skykomish	Forestry Research Center Weyerhaeuser Company Centralia, Washington
Hoskins	School of Forestry Oregon State University Corvallis, Oregon
Rocky Brook	U.S. Forest Service Region 6 and Pacific Northwest Forest and Range Experiment Station Portland, Oregon
Clemons	Forestry Research Center Weyerhaeuser Company Centralia, Washington
Francis	Washington State Department of Natural Resources Olympia, Washington
Iron Creek	U.S. Forest Service Region 6 and Pacific Northwest Forest and Range Experiment Station Portland, Oregon
Stampede Creek	U.S. Forest Service Region 6 and Pacific Northwest Forest and Range Experiment Station Portland, Oregon
Campbell River	Canadian Forestry Service Department of the Environment Victoria, British Columbia
Shawnigan Lake	Canadian Forestry Service Department of the Environment Victoria, British Columbia

Consultative services have been provided by the University of Washington and the U.S. Bureau of Land Management.

ABSTRACT

A calibration thinning and the first treatment thinning in a 20-year-old Douglas-fir stand at Hoskins, Oregon, are described. Data tabulated for the first 7 years of management show that growth changes in the thinned stands were greater than anticipated.

INTRODUCTION

This is the second report in a series on a cooperative levels-of-growing-stock study in Douglas-fir in the Pacific Northwest. The Hoskins study was initiated in 1963 as part of the regionwide program designed to examine the effect of different levels of growing stock on wood production, tree size, and growth-growing stock ratios. Report No. 1 presents the study plan including analysis of data and description of installations.

The Hoskins study area is located approximately 22 miles west of Corvallis near Hoskins, Oregon, on land owned by T. J. Starker and Bruce Starker. The area is immediately east of the summit of the Coast Ranges (fig. 1) on a southern aspect with slopes from 15 to 55 percent. At the time the study was established, the stand was 14 years of age at breast height (total age, 20 years) and contained on the average over 1,700 trees per acre. The study area is site class II. The stand is of natural origin following wildfires.

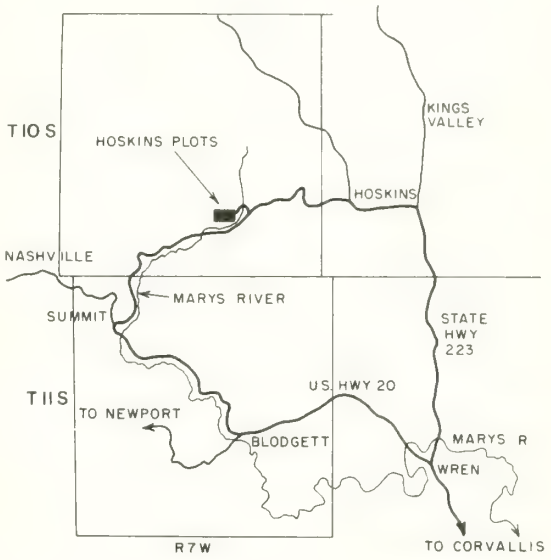

Figure 1.—Location of the Hoskins study.

METHODS

During the summer of 1963, 27 plots, 1/5-acre in size, were established (see appendix, also fig. 2 for map of plot location). Initial density was controlled by a calibration thinning[1/] to a prescribed level of basal area. The basal area per acre at the beginning of the calibration period for the 24 treatment plots ranged between 48.2 square feet and 51.1 square feet compared with 122.0 to 158.3 square feet for the three control plots (table 7). The number of trees per acre on the treatment plots ranged from 290 to 395 compared with 1,610 to 1,885 on the control plots.

[1] For basis of calibration thinning, see Richard L. Williamson and George R. Staebler, 1971. Levels-of-growing-stock cooperative study on Douglas-fir. Report No. 1—Description of study and existing study areas. USDA Forest Serv. Res. Pap. PNW-111, 12 p., illus. Pac. Northwest Forest & Range Exp. Stn., Portland, Oreg.

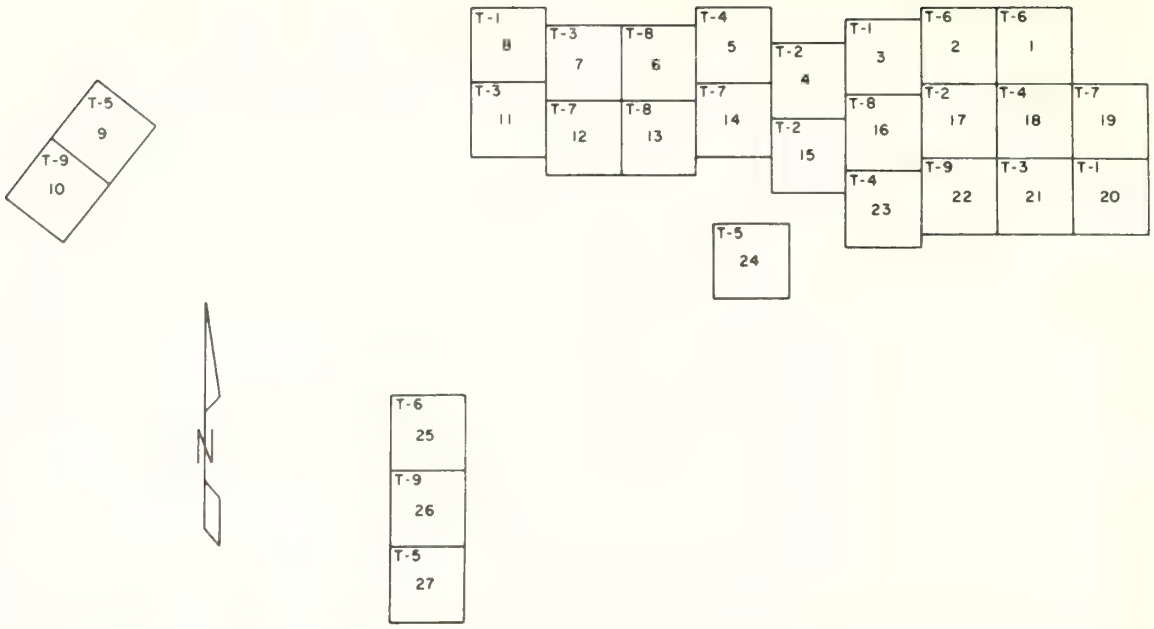

Figure 2. -Layout of Hoskins levels-of-growing-stock study. The plots are one-fifth acre in size.

Crop trees on all plots (including control plots) are numbered 1 through 16 (fig. 3), except plot 26 which has 15 crop trees.

Figure 3.—Picture of plot 22 (control) in 1963. Crop trees have a white circumferential band painted at the point of measurement. Noncrop trees have a different colored band for each treatment and identifying numbers of corresponding color. This facilitates work in the plots and identifies treatments for observers.

At the time of plot establishment, the measurements were made at the conclusion of the 1963 growing season. Height was measured on 340 trees, and these same trees were remeasured at the end of the 1966, 1969, and 1970 growing seasons. D. b. h. of each tree was measured to the nearest 0.1 inch at the end of each growing season, although the study plan called for measurements to be made only at the time of treatment. Annual measurement provides a comparison of diameter and basal area growth among the treatments (see inside front cover for treatments imposed). It also indicates when the response to the treatment occurred.

The periodic diameter, basal area, and increment percent of cubic-foot volume in tables 4 and 5 are calculated using the value at the beginning of the period as the base. For example, the basal area per acre at the outset of the 1964 growing season for treatment 1 was 49. 3 square

feet (table 2), and the basal area increment for treatment 1 for the calibration period was 36.2 square feet (table 4), thus, 36.2/49.3 X 100 = 73.4 percent.

RESULTS AND DISCUSSION

Calibration Period

The calibration period[2/] was three growing seasons (1964-66), based on an average height growth of 9.8 feet for the crop trees (see fig. 4 for a pictorial comparison of plot 8 in 1963 and 1966). Mortality (windthrow) on the thinned plots was minimal and occurred primarily between the first and second growing seasons (table 6). Mortality on the control plots was due to natural suppression and occurred throughout the calibration period.

All Trees

Table 2 presents the basic data for all trees (crop and noncrop) for each treatment by growing season for the 7 years the study has been in existence. The stand table at the beginning of the calibration period is presented in table 9, and the stand table at the end of the calibration period is found in table 10. The basal area increment (table 4) for the first growing season on the control plots was 1-1/2 times that of the thinned plots. Yet, the average number of trees per acre on the control plots (table 2) is approximately five times that of the thinned plots. By the third growing season, the basal area increment for the control and thinned plots was nearly equal (table 4), and there was not a significant difference among the eight treatments and the control (at 95-percent probability level). The total basal area at the beginning of the calibration period in 1964 and the

Figure 4.—Picture of plot 8 after thinning in 1963 (upper) and in 1966 (lower).

[2]Thinnings subsequent to the calibration thinning are made whenever the average height growth of the crop trees on all treatments has increased approximately 10 feet (to the nearest growing season).

basal area increments for each growing season, 1964 through 1966, for all treatments and the control are shown in figure 5. Note the uniformity of growth among the treatments during the calibration period.

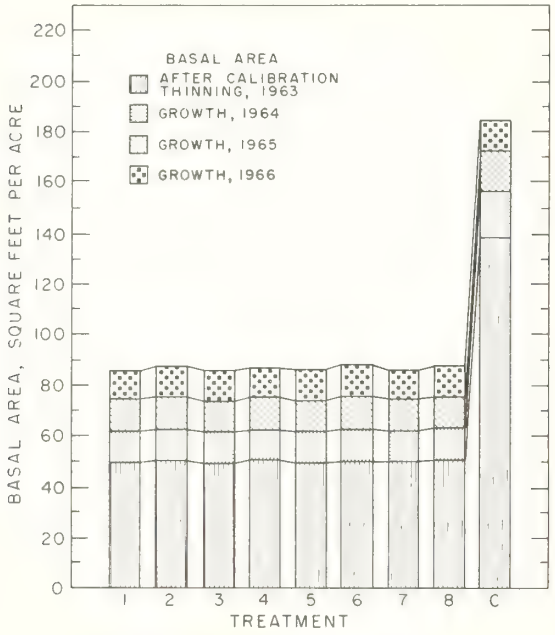

Figure 5.—Basal area by treatment for all trees during calibration period.

Crop Trees

During the calibration period, the average height of the crop trees increased from 36.1 to 45.9 feet (table 1). Table 3 presents other stand data for the crop trees. Table 8 presents basic data by treatment and plot for the crop trees, 1963 through 1970.

Diameter and basal area increment of the crop trees during the first growing season for the eight treatments show that they responded immediately to release. During the calibration period, the basal area increment of the crop trees on the thinned plots was nearly double that of the crop trees on the control plots (table 5 and fig. 7).

First Treatment Period

Following the 3-year calibration period, the first thinning treatments[3] were made between the 1966 and 1967 growing seasons. Data for the trees removed during the first thinning treatment are presented in table 11. The average diameters of trees varied from 6.1 to 6.7 inches. The basal area and cubic-foot volume per tree removed in thinning showed little variation by treatment. There was no mortality on the thinned plots during the first treatment period, but on the control plots mortality increased each year (table 6).

All Trees

In 1967, the first growing season after treatment, the diameter increment among the eight treatments was nearly identical (table 4). In general, the lighter the thinning, the larger the basal area increment. For the 1969 growing season, the basal area increment for each of the eight treatments was greater than that for the control. Yet, the most heavily thinned treatments (1 and 2) had approximately one-third the basal area of the control plots at the end of the 1968 growing season. The basal area increment for each of the eight treatments was nearly double that of the control for the 1970 growing season. The total basal area at the beginning of 1967 and for each

[3] There were in effect only four treatments during the first treatment period—treatments 1 and 2 were treated alike, as were 3 and 4, 5 and 6, and 7 and 8. See inside front cover for treatments imposed.

growing season, 1967 through 1970, for all treatments and the control, is shown in figure 6. Stand tables for 1966 (after thinning) and 1970 are given in tables 12 and 13, respectively.

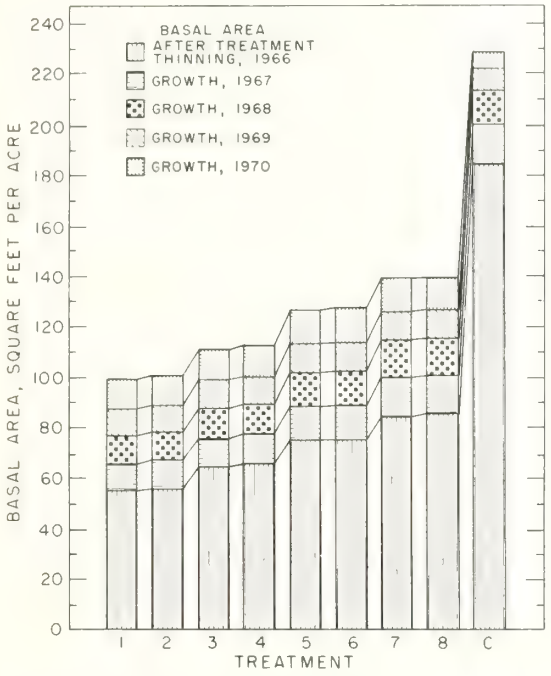

Figure 6.—Basal area by treatment for all trees during first treatment period.

Crop Trees

There was a continued marked increase in the basal area increment of the crop trees on the thinned plots for the first growing season (1967) compared with the crop trees on the control plots (table 5 and fig. 7). During the third and fourth growing seasons after thinning, the crop trees generally responded according to the degree of thinning--that is, the heavier the thinning, the greater the response. For example, the mean basal area per acre of the crop trees for the first growing season for treatments 1 and 2, 3 and 4, 5 and 6, and 7 and 8 ranged from 30.1 to 30.3 square feet with treatments 1 and 2 having the highest value (table 3). The range in mean basal area per acre for these same pairs of treatments in the third year was from 38.2 to 40.5, and the range in the fourth year was from 42.2 to 45.8. Treatments 1 and 2 had the highest values and treatments 7 and 8 the lowest, in each case. Thus, mean basal area per acre varied 0.2 square foot among the pairs of treatments in the first year, increasing to 3.6 square feet by the fourth growing season.

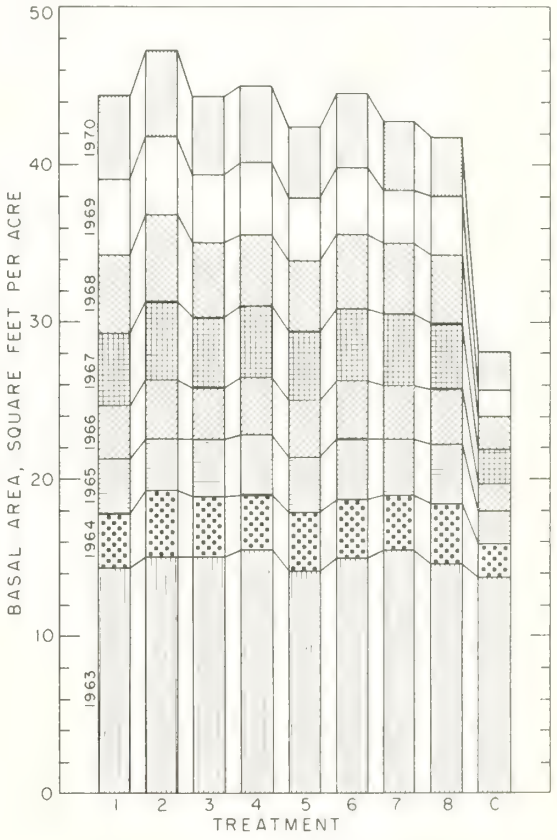

Figure 7.—Basal area by treatment for crop trees.

An analysis of variance comparing basal area increment of crop trees for treatments 1 and 2 with treatments 5 and 6, for the four growing seasons (1967-70), showed there was not a

significant difference (at the 95-percent probability level). However, an analysis of variance comparing basal area increment of crop trees for treatments 1 and 2 (heaviest thinning) with treatments 7 and 8 (lightest thinning) showed there was a significant difference (at the 95-percent probability level) for the three growing seasons (1967-69) and also for the four growing seasons (1967-70).

The percentage of the total growing stock that was represented by the crop trees is given in table 14. Note that the percentage for each treatment (treatments 1-8) was nearly constant from year to year. This indicates that both crop and noncrop trees for a given treatment were growing at the same rate regardless of intensity of thinning. However, the percentage of the total growing stock represented by the crop trees for the control plots had increased from 9.8 percent at the end of the 1963 growing season to 12.3 percent at the end of the 1970 growing season.

SUMMARY

The Hoskins study was established in 1963 as part of a regionwide cooperative program designed to examine the effect of different levels of growing stock on wood production, tree size, and growth-growing stock ratios. This installation was established in 20-year-old Douglas-fir, site class II. The experiment consists of eight treatments plus control replicated three times, making a total of twenty seven 1/5-acre plots in a completely randomized design. A common base for the eight treatments was created by a calibration thinning, with future thinnings to be made whenever the average height of the crop trees on all treatments increases 10 feet.

Preliminary results based on annual measurements for the first 7 years show that substantial changes have occurred in the thinned stand. There was an immediate response in basal area growth after the 1963 calibration thinning. The basal area increment of the thinned plots was nearly equal to the control plots by the third growing season.

The first thinning treatment was applied after the 1966 growing season. By the third growing season, all of the eight treatments had a greater basal area increment than the control plots. In the fourth growing season, the basal area increment for each of the eight treatments was nearly double that of the control.

The basal area increment of the crop trees for the first treatment period (1967-70) was significantly greater at the 95-percent probability level on the most heavily thinned treatments (1 and 2), compared with the most lightly thinned treatments (7 and 8).

The initial results of this study indicate that young Douglas-fir stands provide many opportunities for manipulating the growing stock to achieve the objectives of management.

APPENDIX

Calibration Thinning

Sixty-five man-days were required for locating the area, surveying plot boundaries, marking crop and other leave trees, and making initial measurements and office computations. In addition, 10 man-days were spent in making the final measurements following the calibration thinning.

During the summer of 1963, an Oregon State Forestry Department 30-man emergency fire crew stationed near Corvallis pruned the trees to just above head height to facilitate work on the plots. After the trees were marked for the calibration thinning, the unmarked trees were felled by the State Forestry crew.

The First Treatment Thinning

The following procedure was used to determine level-of-growing-stock for each treatment for the first thinning. Average gross basal area increment per acre in square feet of the three control plots equals net basal area increment plus mortality.

Average basal area increment per acre	= 46.55
Average basal area mortality per acre	= 1.98
Average gross basal area increment per acre	= 48.53

48.53 ÷ 5 = 9.71 gross increment per 1 -acre

Average basal area per plot (one-fifth acre) of the 24 treated plots at end of 1963 growing season was 9.97 square feet.

Basal area level in square feet per treatment at conclusion of first thinning:

Treatments 1 and 2 = 9.97 + 10 percent of 9.71 = 10.94 or 54.70 per acre.
Treatments 3 and 4 = 9.97 + 30 percent of 9.71 = 12.88 or 64.40 per acre.
Treatments 5 and 6 = 9.97 + 50 percent of 9.71 = 14.82 or 74.10 per acre.
Treatments 7 and 8 = 9.97 + 70 percent of 9.71 = 16.77 or 83.85 per acre.

No trees were removed from two of the plots in treatment 7.

Table 1.--*Mean height of crop trees by treatment*[1/]

Treatment number	Number of trees measured	Mean height			
		1963	1966	1969	1970
		----------*Feet*----------			
1	33	35.9	45.3	56.0	59.7
2	30	35.1	46.0	56.7	60.7
3	30	36.1	45.8	56.3	59.6
4	32	36.8	47.3	57.8	61.1
5	31	35.7	45.9	56.8	59.6
6	30	36.7	46.0	56.7	60.2
7	31	35.9	45.3	56.0	59.5
8	33	36.3	45.8	56.3	60.0
Control	35	36.5	45.9	55.3	59.2
All trees	285	36.1	45.9	56.4	59.9
Standard deviation		.53	.58	.48	.61
Coefficient of variation		1.5	1.3	1.2	1.0

[1/] Data are as of the end of the growing season.

Table 2.--*Stand data by treatment for all trees*[1/]
(Per acre)

Treatment number	Number of trees[2/]									Average diameter breast height[3/]								
	Calibration period				First treatment period					Calibration period				First treatment period				
	1963	1964	1965	1966	1966[4/]	1967	1968	1969	1970	1963	1964	1965	1966	1966[4/]	1967	1968	1969	1970
										Inches								
1	353	352	352	352	215	215	215	215	215	5.1	5.7	6.2	6.7	6.9	7.5	8.1	8.7	9.2
2	343	342	342	342	207	207	207	207	207	5.2	5.8	6.3	6.8	7.0	7.7	8.3	8.9	9.4
3	343	343	343	342	252	252	252	252	252	5.1	5.7	6.3	6.8	6.8	7.4	8.0	8.5	9.0
4	333	332	330	330	243	243	243	243	243	5.3	5.9	6.5	6.9	7.0	7.7	8.2	8.7	9.2
5	365	363	363	363	312	312	312	312	312	5.0	5.6	6.1	6.6	6.6	7.2	7.7	8.2	8.6
6	338	338	338	338	283	283	283	283	283	5.2	5.8	6.4	6.9	7.0	7.6	8.1	8.6	9.1
7	328	328	328	328	323	323	323	323	323	5.3	5.9	6.5	6.9	6.9	7.5	8.1	8.5	8.9
8	337	335	335	335	327	327	327	327	327	5.2	5.9	6.4	6.9	6.9	7.5	8.0	8.4	8.8
Control	1,727	1,710	1,687	1,640	1,640	1,595	1,525	1,410	1,272	3.8	4.1	4.3	4.5	4.5	4.8	5.1	5.4	5.7

	Basal area									Total volume[5/]				
	Calibration period				First treatment period					Calibration period		First treatment period		
	1963	1964	1965	1966	1966[4/]	1967	1968	1969	1970	1963	1966	1966[4/]	1969	1970
	Square feet									*Cubic feet*				
1	49.3	61.4	74.1	85.5	55.1	65.7	77.0	87.8	99.5	839	1,770	1,153	2,168	2,588
2	50.0	62.1	75.0	87.1	55.9	67.1	78.3	89.0	100.5	827	1,824	1,180	2,220	2,630
3	49.0	61.6	73.9	85.1	64.4	75.8	88.1	99.1	111.4	845	1,785	1,357	2,464	2,893
4	50.4	62.0	75.0	86.7	65.6	77.9	89.4	100.3	112.7	855	1,835	1,398	2,524	2,970
5	49.2	61.5	73.8	86.0	74.9	88.0	101.7	113.6	126.5	814	1,766	1,546	2,818	3,287
6	49.9	62.6	75.6	88.0	75.1	88.6	102.1	113.7	127.1	854	1,820	1,560	2,816	3,284
7	50.1	62.1	74.3	85.9	84.9	100.0	114.8	126.1	139.4	854	1,777	1,756	3,113	3,627
8	50.4	62.9	75.8	87.8	85.8	100.1	115.2	126.7	139.3	871	1,848	1,807	3,155	3,650
Control	138.1	156.8	172.5	184.7	184.7	200.5	213.7	222.6	228.6	2,318	3,779	3,779	5,353	5,816

1/ Data are as of the end of the growing season.

2/ Rounded to nearest whole tree.

3/ Diameter of tree of mean basal area.

4/ 1966 data minus thinned trees.

5/ Cubic-foot volume derived from table 12 of Richard E. McArdle, Walter H. Meyer, and Donald Bruce. 1961. The yield of Douglas-fir in the Pacific Northwest. U.S. Dep. Agric. Tech. Bull. 201 (rev.), 74 p.

Table 3.--*Stand data by treatment for crop trees*[1/]

(Per acre)

Treatment number	Number of trees	Average diameter breast height[2/]								
		Calibration period				First treatment period				
		1963	1964	1965	1966	1966[3/]	1967	1968	1969	1970
		Inches								
1	80	5.7	6.4	7.0	7.5	7.5	8.2	8.9	9.5	10.1
2	80	5.9	6.7	7.2	7.8	7.8	8.5	9.2	9.8	10.4
3	80	5.9	6.6	7.2	7.7	7.7	8.3	9.0	9.5	10.1
4	80	6.0	6.6	7.2	7.8	7.8	8.4	9.0	9.6	10.2
5	80	5.7	6.4	7.0	7.6	7.6	8.2	8.8	9.3	9.9
6	80	5.9	6.5	7.2	7.8	7.8	8.4	9.0	9.6	10.1
7	80	6.0	6.6	7.2	7.7	7.7	8.4	9.0	9.4	9.9
8	80	5.8	6.5	7.1	7.7	7.7	8.3	8.9	9.3	9.8
Control	80	5.6	6.0	6.4	6.7	6.7	7.1	7.4	7.7	8.0

	Basal area									Volume[4/]				
	Calibration period				First treatment period					Calibration period		First treatment period		
	1963	1964	1965	1966	1966[3/]	1967	1968	1969	1970	1963	1966	1966[3/]	1969	1970
	Square feet									*Cubic feet*				
1	14.4	17.8	21.3	24.7	24.7	29.3	34.3	39.1	44.4	254	529	529	987	1,180
2	15.0	19.3	22.6	26.3	26.3	31.3	36.8	41.8	47.3	257	572	572	1,069	1,269
3	15.1	18.6	22.5	25.8	25.8	30.3	35.1	39.4	44.3	266	556	556	997	1,169
4	15.5	19.0	22.9	26.5	26.5	31.1	35.6	40.2	45.0	275	584	584	1,037	1,209
5	14.2	17.9	21.4	25.0	25.0	29.4	33.9	37.9	42.4	250	541	541	974	1,131
6	15.0	18.7	22.6	26.2	26.2	30.9	35.6	39.8	44.5	269	566	566	1,009	1,178
7	15.6	19.0	22.6	26.0	26.0	30.6	35.1	38.4	42.8	263	555	555	972	1,136
8	14.6	18.4	22.2	25.7	25.7	29.9	34.3	38.0	41.7	260	556	556	971	1,120
Control	13.8	15.9	17.9	19.7	19.7	21.9	24.0	25.7	28.1	246	428	428	660	757

1/ Data are as of end of growing season.

2/ Diameter of tree of mean basal area.

3/ 1966 data minus thinned trees.

4/ Cubic-foot volume derived from table 12 of Richard E. McArdle, Walter H. Meyer, and Donald Bruce. 1961. The yield of Douglas-fir in the Pacific Northwest. U.S. Dep. Agric. Tech. Bull. 201 (rev.), 74 p.

Table 4.-- *Increment data for all trees*

(Per acre)

Treatment number	Diameter breast height increment										Basal area increment										Volume increment[1/]				
	Calibration period					First treatment period					Calibration period					First treatment period					Calibration period, 1964-66		First treatment period		
	1964	1965	1966	Total		1967	1968	1969	1970	Total	1964	1965	1966	Total		1967	1968	1969	1970	Total			1970	Total	
	Inches				Percent	Inches				Percent	Square feet				Percent	Square feet				Percent	Cubic feet	Percent	Cubic feet		Percent
1	0.6	0.5	0.5	1.6	31.4	0.6	0.6	0.6	0.5	2.3	33.3	12.1	12.7	11.4	36.2	73.4	10.6	11.3	10.8	11.7	44.4	90.6	931	110.9	420	1,435	124.5
2	.6	.5	.5	1.6	30.8	.7	.6	.6	.5	2.4	34.3	12.1	12.9	12.1	37.1	74.2	11.2	11.2	10.7	11.5	44.6	79.8	997	120.6	410	1,450	122.9
3	.6	.6	.5	1.7	33.3	.6	.6	.5	.5	2.2	32.4	12.6	12.3	11.2	36.1	73.7	11.4	12.3	11.0	12.3	47.0	73.0	940	111.2	429	1,536	113.2
4	.6	.6	.4	1.6	30.2	.7	.5	.5	.5	2.2	31.4	11.6	13.0	11.7	36.3	72.0	12.2	11.5	11.0	12.4	47.1	71.8	980	114.6	446	1,572	112.4
5	.5	.5	.5	1.6	32.0	.6	.5	.5	.4	2.0	30.3	12.3	12.3	12.2	36.8	74.8	13.1	13.7	11.9	12.9	51.6	68.9	952	116.8	469	1,741	112.6
6	.6	.6	.5	1.7	32.7	.6	.6	.4	.5	2.1	30.0	12.7	13.0	12.4	38.1	76.4	13.5	13.5	11.6	13.4	52.0	69.2	966	113.1	468	1,724	110.5
7	.6	.6	.4	1.6	30.2	.6	.6	.4	.4	2.0	29.0	11.7	12.5	11.2	35.4	70.7	15.1	14.7	11.2	13.3	54.5	64.2	923	109.1	514	1,871	106.5
8	.7	.5	.5	1.7	32.7	.6	.5	.4	.4	1.9	27.5	12.5	12.9	12.0	37.4	74.2	14.3	15.1	11.5	12.6	53.5	62.4	977	112.2	495	1,843	102.0
Control	.3	.2	.2	.7	18.4	.3	.3	.3	.3	1.2	26.7	18.8	15.7	12.2	46.6	33.7	15.8	13.2	8.9	6.0	43.9	23.8	1,461	63.0	463	2,037	53.9

[1/] Volume computed only for the years height was measured.

Table 5.-- *Increment data for crop trees*

(Per acre)

Treatment number	Diameter breast height increment										Basal area increment										Volume increment[1/]				
	Calibration period					First treatment period					Calibration period					First treatment period					Calibration period, 1964-66		First treatment period		
	1964	1965	1966	Total		1967	1968	1969	1970	Total	1964	1965	1966	Total		1967	1968	1969	1970	Total			1970	Total	
	Inches				Percent	Inches				Percent	Square feet				Percent	Square feet				Percent	Cubic feet	Percent	Cubic feet		Percent
1	0.7	0.6	0.5	1.8	31.6	0.7	0.7	0.6	0.6	2.6	34.7	3.4	3.5	3.4	10.3	71.5	4.6	5.0	4.8	5.3	19.7	79.8	275	108.3	193	651	123.1
2	.8	.5	.6	1.9	32.2	.7	.7	.6	.6	2.6	33.3	3.6	4.0	3.7	11.3	75.3	5.0	5.5	5.0	5.5	21.0	79.8	315	122.6	200	697	121.8
3	.7	.6	.5	1.8	30.5	.6	.7	.5	.6	2.4	31.2	3.8	3.6	3.3	10.7	70.9	4.5	4.8	4.3	4.9	18.5	71.7	290	111.1	172	613	110.2
4	.6	.6	.6	1.8	30.0	.6	.6	.6	.6	2.4	30.8	3.5	3.9	3.6	11.0	71.0	4.6	4.5	4.6	4.8	18.5	69.8	309	112.4	172	625	107.0
5	.7	.6	.6	1.9	33.3	.6	.6	.5	.6	2.3	30.3	3.7	3.5	3.6	10.8	76.1	4.4	4.5	4.0	4.5	17.4	69.6	291	116.4	157	590	109.1
6	.6	.7	.5	1.8	30.5	.7	.6	.6	.5	2.3	29.5	3.7	3.9	3.6	11.2	74.7	4.7	4.7	4.2	4.7	18.3	69.8	297	110.4	169	612	108.1
7	.6	.6	.5	1.7	28.3	.7	.6	.4	.5	2.2	28.6	3.4	3.6	3.4	10.4	66.7	4.6	4.5	3.3	4.4	16.8	64.6	292	111.0	164	581	104.7
8	.7	.6	.6	1.9	32.8	.6	.6	.4	.5	2.1	27.3	3.8	3.8	3.5	11.1	76.0	4.2	4.4	3.7	3.7	16.0	62.3	296	113.8	149	564	101.4
Control	.4	.4	.3	1.1	19.6	.4	.3	.3	.3	1.3	19.4	2.1	2.0	1.8	5.9	42.8	2.2	2.1	1.7	2.4	8.4	42.6	182	74.0	97	329	76.9

[1/] Volume computed only for the years height was measured.

Table 6.--*Mortality by treatment of all trees*

(Per acre)

Treatment number	Number of trees					Basal area				
	Calibration period, 1964-66	First treatment period				Calibration period, 1964-66	First treatment period			
		1967	1968	1969	1970		1967	1968	1969	1970
						Square feet				
1	1	0	0	0	0	0.1	0	0	0	0
2	1	0	0	0	0	.2	0	0	0	0
3	1	0	0	0	0	.2	0	0	0	0
4	3	0	0	0	0	.3	0	0	0	0
5	1	0	0	0	0	.3	0	0	0	0
6	0	0	0	0	0	.0	0	0	0	0
7	0	0	0	0	0	.0	0	0	0	0
8	1	0	0	0	0	.2	0	0	0	0
Control	87	45	70	115	138	2.0	1.1	2.1	3.7	5.9
	Average diameter[1/]					Volume[2/]				
	Calibration period, 1964-66	First treatment period				Calibration period, 1964-66	First treatment period			
		1967	1968	1969	1970		1967	1968	1969	1970
	Inches					*Cubic feet*				
1	3.5	0	0	0	0	1.7	0	0	0	0
2	4.2	0	0	0	0	2.2	0	0	0	0
3	4.1	0	0	0	0	2.9	0	0	0	0
4	4.1	0	0	0	0	4.8	0	0	0	0
5	5.4	0	0	0	0	4.5	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	5.0	0	0	0	0	3.7	0	0	0	0
Control	2.1	2.2	2.3	2.4	2.8	27.0	17.7	33.9	66.7	118.9

[1/] Diameter of tree of mean basal area.

[2/] Cubic-foot volume derived from table 12 of Richard E. McArdle, Walter H. Meyer, and Donald Bruce. 1961. The yield of Douglas-fir in the Pacific Northwest. U.S. Dep. Agric. Tech. Bull. 201 (rev.), 74 p.

Table 7.--*Basic data by treatment and plot for all trees*

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Treatment and plot numbers	Number of trees								Diameter[2/]							
	1963	1964	1965	1966	1967	1968	1969	1970	1963	1964	1965	1966	1967	1968	1969	1970
									Inches							
1:																
3	345	345	345	345	210	210	210	210	5.1	5.7	6.4	6.8	7.6	8.3	8.9	9.4
8	380	375	375	375	225	225	225	225	5.0	5.5	6.0	6.4	7.3	7.9	8.4	8.9
20	335	335	335	335	210	210	210	210	5.1	5.8	6.3	6.8	7.6	8.2	8.7	9.3
2:																
4	360	360	360	360	220	220	220	220	5.1	5.6	6.2	6.7	7.5	8.1	8.6	9.2
15	325	325	325	325	185	185	185	185	5.3	5.9	6.5	7.1	8.2	8.9	9.5	10.1
17	345	340	340	340	215	215	215	215	5.2	5.8	6.3	6.8	7.5	8.1	8.6	9.1
3:																
7	390	390	390	390	295	295	295	295	4.8	5.3	5.8	6.3	6.9	7.4	7.9	8.4
11	340	340	340	340	240	240	240	240	5.1	5.8	6.4	6.9	7.7	8.3	8.8	9.4
21	300	300	300	295	220	220	220	220	5.5	6.2	6.7	7.3	7.8	8.4	8.9	9.4
4:																
5	390	390	390	390	285	285	285	285	4.9	5.4	6.0	6.4	7.2	7.7	8.2	8.6
18	320	320	320	320	245	245	245	245	5.3	5.9	6.5	7.0	7.7	8.2	8.7	9.2
23	290	285	280	280	200	200	200	200	5.7	6.3	6.9	7.5	8.3	8.9	9.4	10.0
5:																
9	355	355	355	355	315	315	315	315	5.0	5.6	6.1	6.6	7.2	7.8	8.1	8.6
24	345	345	345	345	280	280	280	280	5.2	5.9	6.4	6.9	7.6	8.2	8.6	9.0
27	395	390	390	390	340	340	340	340	4.8	5.3	5.8	6.3	6.9	7.4	7.9	8.3
6:																
1	325	325	325	325	275	275	275	275	5.3	5.9	6.5	7.0	7.7	8.2	8.7	9.
2	360	360	360	360	300	300	300	300	5.1	5.7	6.3	6.7	7.4	7.9	8.4	8.
25	330	330	330	330	275	275	275	275	5.2	5.9	6.4	7.0	7.7	8.2	8.7	9.
7:																
12	330	330	330	330	330	330	330	330	5.2	5.8	6.4	6.8	7.4	7.9	8.3	8.
14	325	325	325	325	310	310	310	310	5.4	6.0	6.6	7.1	7.7	8.3	8.7	9.
19	330	330	330	330	330	330	330	330	5.3	5.9	6.4	6.9	7.5	8.0	8.4	8.
8:																
6	375	370	370	370	360	360	360	360	5.0	5.6	6.2	6.6	7.2	7.7	8.1	8.
13	330	330	330	330	320	320	320	320	5.3	6.0	6.5	7.0	7.5	8.1	8.5	8.
16	305	305	305	305	300	300	300	300	5.4	6.1	6.7	7.2	7.8	8.4	8.8	9.
Control:																
10	1,885	1,885	1,875	1,830	1,770	1,670	1,555	1,425	3.6	3.8	4.0	4.2	4.5	4.7	5.0	5.
22	1,610	1,565	1,510	1,430	1,395	1,345	1,230	1,110	4.2	4.6	4.8	5.1	5.4	5.6	6.0	6.
26	1,685	1,680	1,675	1,660	1,620	1,560	1,445	1,280	3.6	3.9	4.2	4.3	4.6	4.9	5.2	5.

1/ Data are as of the end of the growing season.

2/ Diameter of tree of mean basal area.

70 (calibration and first treatment periods) [1/]

Basal area								Volume			
63	1964	1965	1966	1967	1968	1969	1970	1963	1966	1969	1970
5	61.6	76.0	88.4	67.0	78.8	90.2	102.1	799.8	1,744.6	2,158.6	2,562.5
2	61.3	73.0	84.2	64.8	75.9	86.4	98.1	879.0	1,762.4	2,180.6	2,620.8
3	61.4	73.3	84.0	65.3	76.4	86.7	98.3	837.0	1,803.8	2,165.2	2,580.6
3	61.5	75.7	87.3	67.4	79.0	89.3	102.2	835.4	1,812.2	2,212.2	2,647.8
1	63.5	75.2	88.3	67.9	79.6	91.4	102.6	854.0	1,938.6	2,321.6	2,741.0
6	61.3	74.3	85.7	65.8	76.2	86.3	96.7	791.9	1,720.4	2,125.0	2,499.8
7	60.3	72.3	83.4	76.6	89.1	100.4	113.1	855.6	1,738.4	2,492.0	2,906.4
3	62.1	75.1	87.2	77.2	89.4	101.5	114.5	845.1	1,819.4	2,531.4	3,021.2
1	62.5	74.2	84.7	73.8	85.6	95.3	106.4	833.8	1,798.5	2,369.0	2,752.3
6	62.2	76.8	88.3	79.7	92.3	103.7	116.2	825.0	1,761.5	2,476.8	2,902.4
6	61.5	74.6	85.9	78.4	89.9	101.1	113.5	808.2	1,805.4	2,563.6	3,020.4
0	62.2	73.5	85.8	75.3	85.8	96.0	108.3	930.8	1,937.1	2,533.0	2,988.2
2	59.7	71.7	83.5	87.7	102.4	113.6	126.5	851.5	1,828.2	2,943.3	3,446.3
7	64.9	77.6	89.9	88.6	101.7	112.5	124.1	794.4	1,798.0	2,730.4	3,163.4
7	59.9	72.0	84.5	87.7	101.1	114.6	128.9	794.6	1,672.0	2,780.8	3,251.2
2	62.2	75.4	87.2	88.0	101.8	113.5	125.3	865.5	1,816.0	2,838.4	3,239.0
5	63.3	76.9	89.1	89.6	103.2	114.8	127.9	847.0	1,782.6	2,783.4	3,221.0
8	62.1	74.4	87.6	88.3	101.4	112.9	128.1	850.5	1,861.3	2,825.3	3,392.1
2	60.7	73.0	83.7	98.6	113.5	123.7	136.7	857.0	1,755.7	3,099.3	3,589.2
0	63.8	76.2	88.5	100.3	115.8	127.4	141.6	893.4	1,884.1	3,173.8	3,691.0
2	61.7	74.5	85.5	101.2	115.2	127.3	139.8	810.0	1,639.8	3,072.3	3,600.3
1	63.1	77.1	88.7	100.7	116.2	128.9	141.4	850.2	1,818.6	3,113.6	3,606.7
0	64.0	76.2	88.1	99.0	114.9	125.0	137.2	880.4	1,811.4	3,075.5	3,521.2
0	61.8	74.2	86.5	100.8	114.6	126.4	139.2	882.8	1,913.6	3,275.1	3,821.3
1	152.0	167.7	178.3	193.9	204.5	212.8	218.7	2,139.2	3,578.0	5,006.4	5,355.0
3	176.5	191.1	201.7	218.5	233.0	240.9	245.9	2,643.9	4,184.2	5,965.0	6,470.2
0	142.0	158.8	174.0	188.9	203.4	214.1	221.3	2,171.4	3,574.9	5,087.9	5,623.4

Table 8.--*Basic data by treatment and plot for crop trees,*

(Per

Treatment and plot numbers	Number of trees	Diameter[2/]							
		1963	1964	1965	1966	1967	1968	1969	1970
		Inches							
1:									
3	80	5.6	6.1	6.8	7.4	8.1	8.8	9.4	10.0
8	80	6.0	6.6	7.2	7.7	8.4	9.0	9.7	10.3
20	80	5.7	6.3	6.9	7.4	8.1	8.8	9.4	9.9
2:									
4	80	5.6	6.2	6.8	7.3	8.0	8.7	9.3	9.9
15	80	6.6	7.7	8.0	8.7	9.4	10.2	10.9	11.6
17	80	5.3	6.0	6.7	7.2	7.9	8.6	9.1	9.7
3:									
7	80	5.7	6.4	6.9	7.4	8.0	8.7	9.2	9.8
11	80	6.2	6.9	7.5	8.1	8.7	9.4	10.0	10.5
21	80	5.8	6.5	7.1	7.6	8.2	8.8	9.3	9.9
4:									
5	80	5.7	6.3	7.0	7.4	8.1	8.7	9.2	9.7
18	80	5.4	6.0	6.6	7.1	7.8	8.4	8.9	9.5
23	80	6.7	7.4	8.1	8.7	9.4	10.0	10.6	11.2
5:									
9	80	5.7	6.3	6.9	7.5	8.1	8.7	9.2	9.8
24	80	5.9	6.7	7.3	7.8	8.5	9.1	9.6	10.1
27	80	5.5	6.2	6.8	7.4	8.0	8.6	9.1	9.7
6:									
1	80	6.0	6.6	7.3	7.9	8.5	9.2	9.7	10.2
2	80	5.6	6.2	6.8	7.4	8.0	8.6	9.1	9.7
25	80	6.0	6.8	7.4	8.0	8.7	9.3	9.8	10.4
7:									
12	80	6.0	6.6	7.2	7.9	8.3	8.9	9.3	9.8
14	80	6.0	6.7	7.3	7.9	8.5	9.2	9.6	10.2
19	80	6.0	6.6	7.1	7.6	8.3	8.8	9.2	9.7
8:									
6	80	5.8	6.5	7.2	7.7	8.3	9.0	9.4	9.9
13	80	6.1	6.8	7.5	8.0	8.5	9.2	9.6	10.0
16	80	5.5	6.2	6.8	7.3	8.0	8.5	8.9	9.4
Control:									
10	80	5.5	6.0	6.3	6.6	7.0	7.2	7.5	7.8
22	80	5.9	6.3	6.6	6.9	7.2	7.5	7.8	8.2
26	80	5.4	5.9	6.3	6.7	7.0	7.4	7.8	8.1

[1/] Data are as of the end of the growing season.

[2/] Diameter of tree of mean basal area.

1963-70 (calibration and first treatment periods)[1/]

acre)

Basal area								Volume				Height of crop trees			
1963	1964	1965	1966	1967	1968	1969	1970	1963	1966	1969	1970	1963	1966	1969	1970
Square feet								*Cubic feet*				*Feet*			
13.5	16.7	20.4	23.8	28.5	33.7	38.6	43.7	224.4	483.4	937.3	1,115.0	34.1	42.7	54.5	58.1
15.7	19.1	22.5	26.1	30.7	35.7	40.7	46.3	290.8	573.0	1,056.3	1,278.8	37.5	46.5	57.5	61.4
14.0	17.5	20.9	24.2	28.7	33.4	38.1	43.1	248.4	530.9	966.4	1,145.8	36.0	46.3	55.6	59.3
13.6	16.7	20.2	23.4	28.2	33.2	37.4	42.8	226.6	492.8	939.2	1,121.9	34.7	45.5	56.6	59.1
19.0	23.5	28.0	32.7	38.6	45.0	51.7	58.3	347.6	758.0	1,358.9	1,610.9	37.9	50.2	60.4	64.7
12.5	15.7	19.5	22.9	27.2	32.1	36.3	40.9	197.4	464.5	907.7	1,073.6	33.2	42.9	54.7	58.3
14.3	17.6	20.9	24.2	28.2	32.7	37.0	41.7	257.4	528.4	947.3	1,109.5	37.0	46.4	57.1	59.8
16.5	20.7	24.6	28.4	33.3	38.3	43.2	48.4	292.2	606.4	1,094.6	1,289.8	37.0	46.2	57.0	61.0
14.5	18.4	21.9	24.9	29.5	34.2	38.0	42.7	247.8	533.6	948.3	1,106.9	34.5	44.8	55.1	58.0
14.3	17.4	21.1	24.2	28.6	32.8	37.0	40.9	244.2	507.8	914.5	1,051.1	35.5	44.5	54.3	56.9
12.9	15.7	19.1	22.1	26.3	30.6	34.8	39.5	209.4	461.7	877.8	1,048.6	34.1	45.3	57.2	60.4
19.4	23.7	28.4	33.2	38.5	43.5	48.9	54.6	370.8	782.4	1,318.4	1,528.6	40.4	52.0	62.3	65.9
14.1	17.4	20.9	24.5	28.7	33.4	37.2	41.6	260.8	562.6	993.8	1,152.8	37.9	49.5	60.1	63.1
15.2	19.5	23.0	26.7	31.6	36.3	40.3	44.7	259.4	568.1	1,017.8	1,180.0	34.4	43.9	54.8	58.4
13.4	16.8	20.3	23.6	27.8	31.9	36.3	41.0	229.8	491.7	909.6	1,060.5	34.8	43.9	55.3	57.2
15.6	19.3	23.5	27.1	31.6	36.6	40.8	45.2	287.0	596.5	1,053.3	1,212.3	36.9	46.4	57.8	61.0
13.5	16.9	20.4	23.7	28.2	32.6	36.5	40.8	232.3	489.8	900.5	1,046.8	35.0	43.8	54.4	57.3
15.7	19.9	23.8	27.9	32.8	37.5	42.1	47.4	288.5	610.6	1,074.2	1,275.4	38.3	47.8	58.0	62.2
15.5	18.9	22.4	25.7	30.3	34.4	37.8	41.6	275.2	551.0	963.8	1,107.0	36.8	46.2	57.4	60.4
15.6	19.3	23.1	27.1	31.7	36.9	40.4	45.5	277.4	591.7	1,023.8	1,208.2	37.0	46.7	56.5	60.0
15.7	18.8	22.2	25.2	29.7	33.9	37.1	41.2	236.1	521.4	929.1	1,093.5	34.0	43.3	54.4	58.0
14.6	18.3	22.5	26.0	30.1	35.0	38.8	42.9	257.2	564.5	995.6	1,152.4	35.5	45.3	55.7	59.2
16.1	20.1	23.9	27.6	31.8	36.6	40.3	43.9	287.4	585.0	1,014.8	1,152.6	36.6	45.1	55.9	59.1
13.0	16.7	20.1	23.5	27.7	31.4	34.8	38.3	234.6	519.6	902.4	1,054.2	36.9	47.1	57.5	61.8
13.4	15.4	17.4	18.9	21.1	22.9	24.5	26.3	235.2	403.6	617.4	690.4	36.5	45.6	55.3	58.3
15.3	17.2	19.2	20.7	22.9	24.8	26.4	29.6	281.6	466.6	698.9	822.6	37.2	46.8	56.0	60.8
12.7	15.0	17.3	19.4	21.6	24.2	26.3	28.3	222.2	414.2	664.6	756.8	35.7	45.0	54.5	58.5

Table 9.--*Stand table after calibration thinning, 1963*[1/]

(Number of trees per acre)

D.b.h. class (inches)	Treatment number								
	1	2	3	4	5	6	7	8	Control
2	2	--	--	--	--	--	--	--	533
3	28	42	43	33	45	32	33	32	420
4	123	75	100	80	105	85	75	83	357
5	105	123	97	105	118	118	92	110	225
6	63	72	75	77	77	65	92	70	118
7	32	30	17	33	17	37	28	33	43
8	--	2	8	3	3	2	8	7	5
9	--	--	3	2	--	--	--	2	2
10	--	--	--	--	--	--	--	--	2
Total	353	344	343	336	365	339	328	337	1,725

[1/] Rounded to nearest whole tree.

Table 10.--*Stand table for end of calibration period, 1966*[1/]

(Number of trees per acre)

D.b.h. class (inches)	Treatment number								
	1	2	3	4	5	6	7	8	Control
2	--	--	--	--	--	--	--	--	307
3	2	--	--	--	--	--	--	2	407
4	23	33	25	20	32	18	22	23	333
5	58	48	67	52	70	47	55	52	243
6	102	97	97	77	93	92	63	83	165
7	87	72	62	85	85	92	85	75	112
8	43	57	55	52	67	48	65	57	50
9	30	33	25	33	12	37	28	30	15
10	7	7	8	5	8	5	8	10	3
11	--	--	3	0	--	--	--	3	3
12	--	--	--	2	--	--	--	--	2
Total	352	347	342	328	367	339	326	335	1,640

[1/] Rounded to nearest whole tree.

Table 11.--*Trees removed in first treatment thinning, 1966*

(Per acre)

Treatment number	Number of trees[1/]	Average d.b.h.	Basal area		Volume	
			Total	Per tree	Total	Per tree
		Inches	*-----Square feet------*		*------Cubic feet------*	
1	137	6.4	30.4	0.220	612.40	4.47
2	135	6.5	31.2	.230	643.70	4.77
3	90	6.5	20.7	.230	428.30	4.76
4	87	6.7	21.1	.245	436.25	5.07
5	51	6.2	11.1	.215	218.60	4.20
6	55	6.5	12.9	.235	260.00	4.73
7	5	6.1	1.0	.205	20.80	4.16
8	8	6.7	2.0	.250	40.45	5.06

[1/] Rounded to nearest whole tree.

Table 12.--*Stand table after first treatment thinning, 1966*[1/]

(Number of trees per acre)

D.b.h. class (inches)	Treatment number								
	1	2	3	4	5	6	7	8	Control
2	--	--	--	--	--	--	--	--	307
3	--	--	--	--	--	--	--	2	407
4	15	15	22	17	25	13	20	23	333
5	28	25	43	34	67	42	53	50	243
6	62	52	73	57	72	73	63	82	165
7	53	48	40	57	71	73	82	70	112
8	25	38	42	40	60	40	65	57	50
9	25	22	20	33	10	35	28	30	15
10	7	5	8	5	8	5	8	10	3
11	--	--	3	0	--	--	--	3	3
12	--	--	--	2	--	--	--	--	2
Total	215	205	251	245	313	281	319	327	1,640

[1/] Rounded to the nearest whole tree.

Table 13.--*Stand table at end of first treatment period, 1970*[1/]

(Number of trees per acre)

D.b.h. class (inches)	Treatment number								
	1	2	3	4	5	6	7	8	Control
2	—	--	--	--	--	--	--	--	53
3	--	--	--	--	--	--	--	--	223
4	--	2	2	2	2	2	2	2	267
5	3	5	5	8	15	7	10	20	220
6	15	15	28	15	35	22	35	28	172
7	23	12	38	35	50	27	40	48	125
8	47	37	47	40	60	65	50	58	103
9	48	47	45	45	63	65	77	63	58
10	37	37	37	40	55	42	62	55	30
11	15	27	25	40	18	35	28	27	12
12	23	20	18	12	7	18	13	18	3
13	3	7	3	5	7	2	7	7	3
14	--	--	3	2	--	--	--	--	--
15	--	—	--	--	--	--	--	--	2
Total	214	209	251	244	312	285	324	326	1,271

[1/] Rounded to the nearest whole tree.

Table 14.--*Percent of growing stock in crop trees*

Treatments	Calibration period					
	Basal area		Number of trees		Cubic-foot volume	
	1963	1966[1/]	1963	1966[1/]	1963	1966[1/]
Thinned	29.9	29.8	23.4	23.5	31.0	30.9
Control	9.8	10.4	4.5	4.8	10.4	11.1

	First treatment period											
	Basal area				Number of trees				Cubic-foot volume			
	1967	1968	1969	1970	1967	1968	1969	1970	1967	1968	1969	1970
1 and 2	45.9	45.8	45.8	45.8	37.9	37.9	37.9	37.9	47.2	46.9	46.8	46.9
3 and 4	39.9	39.8	39.9	39.8	32.3	32.3	32.3	32.3	41.4	40.9	40.8	40.6
5 and 6	34.1	34.1	34.2	34.3	26.9	26.9	26.9	26.9	35.6	35.5	35.2	35.1
7 and 8	30.3	30.2	30.2	30.3	24.6	24.6	24.6	24.6	31.2	31.1	31.0	31.0
Control	10.4	11.1	11.5	12.3	4.8	5.1	5.7	6.3	11.1	11.7	12.9	13.0

[1/] End of 1966 growing season prior to thinning.

Other LOGS (levels-of-growing-stock) reports :

WILLIAMSON, RICHARD L., and GEORGE R. STAEBLER
1965. A cooperative level-of-growing-stock study in Douglas-fir. USDA Forest Serv. Pac. Northwest Forest & Range Exp. Stn., 12 p., illus. Portland, Oreg.

Describes purpose and scope of a cooperative study which is investigating the relative merits of eight different thinning regimes. Main features of six study areas installed since 1961 in young stands are also summarized.

WILLIAMSON, RICHARD L., and GEORGE R. STAEBLER
1971. Levels-of-growing-stock cooperative study on Douglas-fir. Report No. 1--Description of study and existing study areas. USDA Forest Serv. Res. Pap. PNW-111, 12 p., illus. Pac. Northwest Forest & Range Exp. Stn., Portland, Oreg.

Thinning regimes in young Douglas-fir stands are described. Some characteristics of individual study areas established by cooperating public and private agencies are discussed.

Bell, John F., and Alan B. Berg
1972. Levels-of-growing-stock cooperative study on Douglas-fir. Report No. 2--The Hoskins study, 1963-1970. USDA Forest Serv. Res. Pap. PNW-130, 19 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Thinning regimes in a young Douglas-fir stand near Hoskins, Oregon, are described. Data are tabulated for the first 7 years of management.

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Lumber Recovery From Douglas-fir Thinnings at a Bandmill and Two Chipping Canters

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ABSTRACT

Trees cut in thinning of Douglas-fir stands were processed into lumber at a profiled cant chipper, a square cant chipper with resaw, and a bandmill.

Results are reported in terms of both cubic feet and Scribner long log scale. Included are tables by log input by diameter class for three studies, recovery by lumber grade and dimension item for three studies, and value and recovery by diameter class for the square and profiling canters. Recovery totals for all three studies in both lumber and chips are also reported.

Keywords: Lumber, recovery ratios, thinning (trees), sawmill equipment.

INTRODUCTION

Commercial thinning of young Douglas-fir stands is a rapidly increasing portion of the total timber harvested in the Pacific Northwest. New logging and sawmilling equipment and increasing demand for forest products have combined to make operations in younger and smaller stands commercially feasible. Very little information is available on lumber grade recovery, overrun, or chip recovery from this portion of the resource.

In 1968 Region 6 of the National Forest System in cooperation with the Pacific Northwest Forest and Range Experiment Station, the Bureau of Land Management, and three mills initiated a series of lumber recovery studies on thinning materials from Douglas-fir stands. The material was processed between January and April 1970 through a conventional bandmill, a 10-inch-maximum cant-size square-canting chipper (Beaver) with resaw, and a 12-inch-center-cant profiling chipper with double arbor circular saws for cant breakdown (Chip-N-Saw Model 1242-60).[1/]

The information on lumber and chip recovery will be useful to mill operators and timber managers in predicting product yields of logs from similar stands and in evaluating different production methods as logs of this type are used more.

[1] *Mention of companies or products does not constitute endorsement by the U.S. Department of Agriculture.*

STUDY PROCEDURES

TIMBER SAMPLING AREAS

The samples were taken from well-stocked Douglas-fir stands less than 100 years old (table 1) located on the Mount Hood National Forest in Oregon. The sample trees were selected to improve growing conditions for the thriftier trees, to salvage incipient or existing mortality, or to improve stand spacing. The material processed at the Chip-N-Saw and at the bandmill was from the same stand, with only a road separating the two areas. The material processed at the Beaver was from two widely separated stands.

Because the bandmill had no effective diameter limit, some larger trees were included in the sample (tables 1 and 2).

LOG SCALING AND GRADING

The woods-length logs were scaled and graded in the mill yard by a U.S. Forest Service check scaler. Scaling was according to uniform scaling bureau rules for west side,[2/] with logs up to 40 feet in length being scaled as one piece. Logs were graded according to rules for Douglas-fir logs in the standing tree.[3/] Defects not visible on the log surface were not considered in grading.

[2] *Official log scaling and grading rules. Revised as needed.*

[3] *Log grade descriptions for Douglas-fir. Form R6-2440-19D (March 1965). Unpublished material on file at U.S. Forest Serv., Region 6, Portland, Oreg.*

Table 1.--Stand characteristics of sampling areas

Characteristic	Clackamas County		Hood River County	
	Beaver	Beaver	Chip-N-Saw	Bandmill
Stand age (years)	55	85	65	65
Site class	III	III	III	III
Basal area/acre (square feet)	225	215	200	200
Basal area cut/acre (square feet)	41	45	43	43
Average d.b.h. (inches)	9.5	10.0	10.0	10.6
D.b.h. range (inches)	7-14	7-16	6-15	7-18
Log scaling defect (percent)	1	1	4	3

Table 2.--Log input by diameter class as a percent of net Scribner scale and gross cubic volumes

Diameter (inches)	Beaver			Chip-N-Saw			Bandmill		
	Number	Scribner	Cubic	Number	Scribner	Cubic	Number	Scribner	Cubic
	- - -

CUBIC MEASUREMENTS

Cubic measurements were made on sawmill length, bucked and barked logs. The cubic volume of a wood length log was determined by adding the cubic volume of the mill length segments, with diameters recorded to the nearest inch. The cubic volume of the segments was determined by Smalian's formula. No deductions were made from gross cubic volume measurements. Cubic volumes of lumber were calculated by computer, based on sample measurements of actual rough green lumber width and thickness and on nominal lumber lengths.

PROCESSING AND INDIVIDUAL MILL SETUP

In the woods each mill length log was given a number identifying the tree and the log position in the tree. At the mill, lumber was identified with the mill length and scaling length log and tree from which it came.

The bandmill had a debarker, band headrig for primary breakdown, reciprocating gangsaw, two edgers, a vertical band resaw, and gang trim saw. Grading and tallying of boards was done on the green chain. Due to very difficult conditions in the mill, several errors were made in assigning log sequential numbers to some or all of the boards from several logs. Recovery by log or by diameter class cannot be accurately given. However, total log scale in and total lumber recovery out can be compared with the other two studies.

The equipment with the Beaver included a debarker, vertical band resaw with recycling chains, an edger, and a 24-foot gang trim saw. Grading and tallying were done on the green chain.

The output from the Chip-N-Saw was put into the production flow from a conventional mill which was sawing other lumber also. The edger and trim saw were inside the main mill. Grading and tallying were done on the chain from the canter to the main mill. Because of plant layout there was more pencil trim and rip[4] at this mill than at the other two, but because of the soundness of the material, less than 10 percent of the total pieces were either trimmed or ripped.

CHIP RECOVERY

At all three mills, an empty chip bin or car was provided. All study chips were put in one shipment. The weight and moisture content of the chips were determined in the standard manner by the chip purchaser, and the total number of ovendry tons was determined from the shipment or car number. At the Chip-N-Saw, material pencil trimmed or ripped was excluded from the lumber tally. Since actual trimming or ripping was done at the main mill, these chips were not included in the reported chip recovery. The actual chip recovery would be very little higher than reported here. Pencil trim and rip at the other two mills would be insignificant.

LUMBER GRADING

All lumber was graded in the rough green condition by inspectors from the West Coast Lumber Inspection Bureau or Pacific Lumber Inspection Bureau. Each piece was given its anticipated surfaced

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[4] *Reduction in length or width marked by the grader when he assumed such remanufacture would be done beyond the point at which he was grading.*

green grade.[5] Pencil trim and rip, or both, were also designated by the grade inspector. Pencil trim was used to upgrade a board only when it could reasonably be assumed that the same decision would be made at the planer chain.

LUMBER TALLY

Lumber was tallied by Forest Service crews working immediately after the grader. Each board was tallied by width, thickness, length, grade, and the identification number of the log from which it came. Pencil trim and rip were deducted from the actual length and width as the boards were tallied.

RESULTS AND CONCLUSIONS

The results are listed in a series of tables (tables 3-6). Table 3 is the lumber recovery by lumber grade and dimension item for each of the study mills. Table 4 is the recovery by lumber grade for each log diameter class for the Beaver and Chip-N-Saw, and the totals for the bandmill. Table 5 is the total value and volume, recovery per unit volume, and value per unit volume by diameter class for the Beaver and Chip-N-Saw and totals for the bandmill. Table 6 summarizes information from the other tables and includes chip recovery.

The tables are set up to allow the user to supply any set of grade, item, or chip prices to recompute values. The values assigned to various grades and items can produce wide variations in total and unit values.

Diameter limits expressed in the grading rules caused all logs at both the Beaver and the Chip-N-Saw to be graded Number 3 Sawmill. There were 19 logs at the bandmill large enough to be graded Number 2 Sawmill. Since individual log recovery was not obtained at the bandmill, there was no analysis by grade. This refinement is probably not necessary since, other than diameter, there were no external differences between grade 2 and grade 3 logs.

Among the three mills, there were some obvious differences in the volume and grade of lumber items produced, as well as in the volume of chips per unit of log input.

These differences bear out the common assumption that a bandmill will produce more overrun and less chips than a chipping type headrig. It is also commonly held that most of the increase in overrun at a bandmill will be in the form of 1-inch lumber. The bandmill overrun was 168 percent compared with 138 percent for the Beaver. Of this difference only 16 percent could be attributed to differences in 1-inch lumber production. Of the bandmill's 29-percent difference from the Chip-N-Saw, only 6 percent was attributable to 1-inch boards. Evidently the versatility of the bandmill increases recovery of more than just 1-inch boards.

The ability to vary production by lumber size was very limited on the Chip-N-Saw. The bandmill was virtually unlimited but heavily weighted toward 2-inch dimension by the gang saw. The Beaver, except for the initial 10- by 10-inch cant size, was limited only by resaw capacity. A large majority of the

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[5] *West Coast Lumber Inspection Bureau. Number 15, Standard grading and dressing rules for Douglas fir west coast hemlock, Sitka spruce, western red cedar lumber. Rev. Feb. 15, 1968. Portland, Oreg.*

Table 3.--Percent of total production by grade, dimension, and mill

Dimension (inches)	Select Structural	Construction	Standard	Utility	Economy	Total
			Percent			
Beaver:						
1 x 4	--	[1/]0.54	0.04	0.05	0.02	0.65
1 x 6	--	[2/].33	.03	[2/].05	.04	.45
2 x 3	--	1.10	.38	.16	.04	1.68
2 x 4	5.16	17.58	4.65	1.85	.38	29.62
2 x 6	4.32	7.92	2.84	.72	.46	16.26
2 x 8	1.13	1.38	.70	.03	--	3.24
2 x 10	--	.05	--	--	--	.05
4 x 4	3.09	41.50	2.97	.49	--	48.05
Total	13.70	70.40	11.61	3.35	.94	100.00
Chip-N-Saw:						
1 x 4	3.53	3.07	0.56	0.47	0.21	7.84
1 x 6	.02	[3/].20	.12	.12	[3/].28	.74
2 x 4	13.17	20.28	5.32	3.55	1.65	43.97
2 x 6	11.47	15.19	2.49	1.80	.82	31.77
2 x 8	5.59	6.63	.48	.28	.24	13.22
2 x 10	.83	1.14	.42	.07	--	2.46
Total	34.61	46.51	9.39	6.29	3.20	100.00
Bandmill:						
1 x 3	0.01	0.47	0.12	0.05	0.01	0.66
1 x 4	.37	6.22	1.56	.79	.29	9.23
1 x 6	.01	.37	.09	.05	--	.52
1 x 8	--	[4/].05	.02	--	--	[4/].07
2 x 3	.03	.37	.03	.02	--	.45
2 x 4	2.82	20.35	4.27	1.67	.62	29.73
2 x 6	1.86	19.78	7.70	2.11	.26	31.71
2 x 8	.91	11.50	5.75	1.05	--	19.21
2 x 10	.45	3.90	2.31	.54	--	7.20
2 x 12	.07	.53	.12	--	--	.72
3" & thicker, 4" & wider	.04	.30	.15	--	.01	.50
Total	6.57	63.84	22.12	6.28	1.19	100.00

[1/] Includes 0.01 percent 1 x 3.

[2/] Includes 0.05 percent 1 x 8.

[3/] Includes 0.01 percent 1 x 8.

[4/] Includes 0.02 percent 1 x 10.

Table 4.--Lumber grade recovery as a percent of lumber tally volume by diameter class and mill

Diameter (inches)	Number of logs	Select Structural	Construction	Standard	Utility	Economy
			Percent			
Beaver:						
4	46	7.6	73.2	11.3	4.6	3.3
5	285	10.0	75.6	10.7	3.2	.5
6	199	8.1	78.0	8.8	3.4	1.7
7	161	13.1	69.3	13.7	3.1	.8
8	137	16.1	66.7	12.4	3.8	1.0
9	62	22.7	63.7	11.0	1.9	.7
10	32	16.1	65.0	14.5	4.2	.2
11	4	21.8	52.5	7.5	18.2	--
Total	926	13.7	70.4	11.6	3.4	.9
Chip-N-Saw:						
4	28	13.2	30.7	23.2	23.8	9.1
5	244	27.8	50.6	11.2	6.8	3.6
6	101	34.1	47.5	9.6	5.9	2.9
7	63	34.0	47.8	8.4	7.8	2.0
8	74	44.6	43.7	5.7	3.9	2.1
9	32	36.5	46.8	7.8	5.7	3.2
10	17	38.7	43.4	9.4	3.7	4.8
11	6	38.7	35.2	12.3	9.3	4.5
Total	565	34.6	46.5	9.4	6.3	3.2
Bandmill, Total	567	6.6	63.8	22.1	6.3	1.2

Table 5.--Lumber recovery and value per unit volume by log diameter class for three mills

Diameter (inches)	Scribner		Lumber tally		Cubic volume			Ratio of board-foot lumber tally to cubic log volume	Value[1/]			
	Gross board feet	Net board feet	Total board feet	As percent of net scale	Gross volume logs	Volume of lumber	Percent recovered as lumber		Total	Dollars/MBF lumber tally	Dollars/MBF net log scale	Dollars/M cu.ft. gross log volume
Beaver:												
4	830	830	1,315	158	248.9	110.8	45	5.28	130.26	99.06	156.94	523.34
5	5,080	5,040	9,303	185	1,672.9	790.3	47	5.56	943.14	101.38	187.13	563.78
6	7,010	6,900	7,987	116	1,553.4	682.9	44	5.14	802.93	100.53	116.37	516.89
7	7,500	7,370	9,291	126	1,836.7	791.7	43	5.06	940.44	101.22	127.60	512.03
8	7,770	7,680	10,885	142	2,103.8	926.5	44	5.17	1,097.53	100.83	142.91	521.69
9	4,470	4,380	6,155	141	1,131.9	524.5	46	5.44	626.15	101.73	142.96	553.18
10	2,770	2,760	3,301	120	564.5	281.2	50	5.85	334.06	101.20	121.04	591.78
11[2/]	340	340	362	106	71.7	31.0	43	5.05	34.79	96.11	102.32	485.22
Total	35,770	35,300	48,599	138	9,183.8	4,138.9	45	5.29	4,909.30	101.02	139.07	534.56
Chip-N-Saw:												
4	410	380	736	194	98.6	59.0	60	7.46	64.89	88.17	170.77	735.96
5	4,850	4,690	9,646	206	1,661.9	773.1	47	5.80	945.69	98.04	201.64	569.04
6	4,420	4,100	4,301	105	850.9	344.9	41	5.05	424.85	98.78	103.62	499.29
7	3,330	3,210	3,516	110	697.4	284.0	36	5.04	347.03	98.70	108.11	497.61
8	5,060	4,940	6,335	128	1,113.8	515.1	46	5.60	634.07	100.09	128.35	569.29
9	3,030	2,920	4,035	138	649.8	327.3	50	6.21	398.29	98.71	136.40	612.94
10	1,900	1,880	2,262	120	379.3	184.0	48	5.96	222.65	98.43	118.43	587.00
11	920	880	1,115	127	177.7	90.7	51	6.27	107.63	96.53	122.31	605.68
Total	23,920	23,000	31,946	139	5,629.4	2,578.1	46	5.67	3,145.10	98.45	136.74	558.69
Bandmill, Total	26,820	26,050	43,754	168	6,381.4	3,227.5	51	6.86	4,365.33	99.77	167.76	684.07

1/ Lumber prices used are: Standard & Better, $102.89; Utility, $65.62; Economy, $38.65.

2/ Maximum capacity, 10-inch by 10-inch cant.

Table 6.--Summary of three processing alternatives

Characteristic	Beaver	Chip-N-Saw	Bandmill
Average weighted scaling diameter	6.6	6.4	6.6
Percent defect	1	4	3
Percent Select Structural[1/]	13.7	34.6	6.6
Percent Construction[1/]	70.4	46.5	63.8
Percent Standard[1/]	11.6	9.4	22.1
Percent Utility[1/]	3.4	6.3	6.3
Percent Economy[1/]	.9	3.2	1.2
Overrun percent	38	39	68
Percent cubic recovered as lumber	45	46	51
$/MBF lumber tally[2/]	101.02	98.45	99.77
$/MBF net log scale[3/]	139.07	136.74	167.76
$/M cubic feet	534.56	558.69	684.07
Chip recovery, dry tons[4/]	77.63	[5/]35.80	25.48
Dry tons/M net log scale	2.20	1.56	.98
Dry tons/M cubic feet of logs	8.453	6.360	3.993

[1/] West Coast Lumber Inspection Bureau. No. 15, Standard grading and dressing rules for Douglas fir, west coast hemlock, Sitka spruce, western red cedar lumber. Rev. Feb. 15, 1968. Portland, Oreg.

[2/] Lumber prices used are: Standard & Better, $102.89; Utility, $65.62; Economy, $38.65.

[3/] Official log scaling and grading rules. Revised as needed.

[4/] 1 dry ton equals 2,000 pounds of ovendry chips.

[5/] Does not include chips from trimming or edging done in the main sawmill (estimated maximum 0.30 dry ton).

4x4's produced at the Beaver were produced by resawing larger cants.

Although the variation in lumber *grades* is partly a function of the items produced, it seems to be largely due to variations in sawing and trimming decisions. There was little variation in knot size among trees from the different samples. The difference in the percent of utility was largely due to mismanufacture and defects not trimmed; economy lumber was apparently related to the difference in percent of scaling defect among the mills. This relationship occurs in most lumber recovery studies.

One reason for the high percentage of Select Structural lumber from the Chip-N-Saw was the production of lumber with very little wane. Under the provisions of standard grading and dressing rules for Douglas-fir[6/] and given a limited variation in knot size, wane would be the most important single factor in degrading lumber from Select Structural to Construction or Standard grade.

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6 See footnote 4.

Fahey, Thomas D., and Douglas L. Hunt
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Keywords: Lumber, recovery ratios, thinning (trees), sawmill equipment.

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1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

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USDA FOREST SERVICE
RESEARCH PAPER PNW-13

SAW LOGS IN TREES GRADING SUGAR PINE

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ABSTRACT

Small limbs and small overgrown limbs cause problems when grading saw logs in sugar pine trees. Surface characteristics and lumber recovery information for 426 logs from 64 sugar pine trees were examined. Resulting modifications in the grading specification that allow a grader to ignore small limbs and small limb indicators do not appear to decrease the performance of the grading system.

Keywords: Sugar pine, log grades.

INTRODUCTION

In 1962, specifications for an improved system for grading ponderosa pine (*Pinus ponderosa* Laws.) and sugar pine (*Pinus lambertiana* Dougl.) saw logs in trees were published.[1/] A supplementary publication provided detailed information on the identification, definition, and significance of surface imperfections visible on ponderosa and sugar pine logs.[2/] Together they provided a single standardized grading system for ponderosa and sugar pine. This improved system is used by foresters and cruisers in various operations requiring log grading.

Specifications for the improved grades are briefly summarized as follows:

	Defects Permitted	
Grade	*Primary (log knots)*	*Secondary (scars, etc.)*
1	One log knot not over one-half-inch diameter	Confined to three panels or less
2	Confined to four panels or less	Secondary plus primary confined to six panels or less
3	Six panels free of all grading defects	
4	(a) 80 percent bark limbs (b) Bark limbs not exceed one-sixth log diameter; other log knots not exceed one-twelfth log diameter (c) Not more than 24 near maximum size	Confined to three panels or less
5	All other logs, if net scale one-third or more of gross scale	

[1] *Edward M. Gaines. Improved system for grading ponderosa pine and sugar pine saw logs in trees. USDA Forest Serv. Pac. Southwest Forest & Range Exp. Stn. Tech. Pap. 75, 21 p., illus., 1962.*

[2] *Willard L. Jackson. Guide to grading defects in ponderosa and sugar pine logs. USDA Forest Serv. Pac. Southwest Forest & Range Exp. Stn., 34 p., illus., 1962.*

In grading specifications, all limbs, limb stubs, and overgrown limbs[3] are classified as primary defects. They are termed log knots.

Secondary defects include scars of all types, burls, forks, crooks, cankers, and cracks due to natural causes. They have to be recognized and grouped into panels. A panel is a unit of log surface used to define extent of defect grouping or extent of defect-free areas. The size of a panel is one-quarter the log circumference by 4 feet long. Panels are located individually and may be scattered over the log surface.

Problems are encountered in applying the specifications to sugar pine. The texture and dark color of sugar pine bark masks small dead limbs and overgrown limbs so that they are not readily visible (fig. 1). They are difficult to recognize and group into panels as specified in the Improved Grading System. As a result, a large amount of time is spent in grading. Failure to obtain consistent grading results is a related problem.

The problems encountered in applying the grading specifications to sugar pine would be alleviated if small limbs and indicators of overgrown limbs were eliminated from the primary defect classification. If they were not classified as defects, they could be ignored in grading. However, these changes in the grading specifications could reduce the system's performance in estimating the value of logs. This might be undesirable, depending on the cost of considering the indicator specification and the degree of performance reduction. There is also the question of the proper definition of a small limb: 1/2-inch, 1-inch, or some other size.

Discussions of these problems with managers of sugar pine stands and users of the grading system resulted in a study of various modifications in the improved grading system. A modification was sought that would reduce the problems connected with application of the specifications and would perform acceptably. The results of this study are presented for the information and consideration of those concerned with grading sugar pine trees.

PROCEDURE

A review of the work leading to the improved system showed that information on more than 8,900 logs had been used to develop the system. The information consisted of lumber recovery data and detailed records of surface characteristics for individual logs. About 600 of these logs were sugar pine. The information on these logs had been obtained in two mill studies conducted in central and northern California. In these studies, logs had been selected in the mills' log yards. There, detailed diagrams were made of the surface characteristics.

Review of these diagrams indicated that very few of the small limbs and overgrown limbs illustrated in figure 1 were noted as being present on the logs. It is probable that the logging and handling operations that preceded the diagraming phase of these

[3] *Also known as knot indicators. They are scars or bark distortions that indicate the presence of a knot in the underlying wood.*

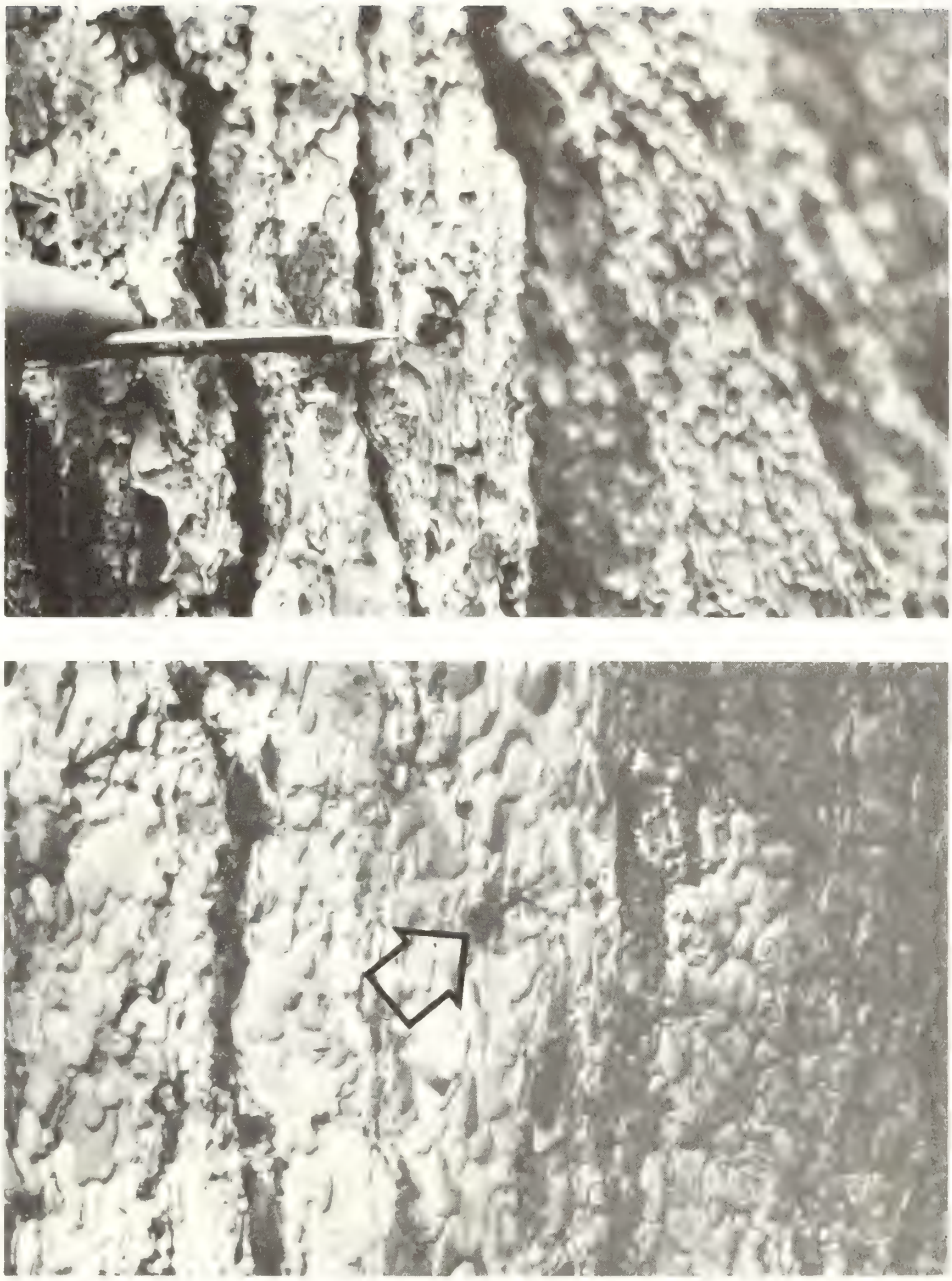

Figure 1.—Examples of small overgrown limbs in sugar pine logs that are difficult to recognize and group into panels for grading.

studies obliterated many of the small surface characteristics that caused application problems. It is also probable that many of the small surface characteristics were not diagramed because they were not considered significant. Since the available data did not appear to be adequate, a new set of data was obtained for the study.

During the summer and fall of 1970, surface characteristics and lumber recovery information were obtained on a sample of sugar pine logs. This information was obtained in cooperation with the Pacific Northwest Region of the National Forest System. Sixty-four trees were selected from five timber stands tributary to Medford, Oregon. The location, type, and size-of-surface characteristics present on the butt 32-foot portion of the tree stems were recorded (diagramed) while the sample trees were still standing. This was done with the use of a graduated 32-foot pole and 6x35 binoculars. After the trees were felled, but prior to logging, this record was checked and the characteristics present on the upper portion of the tree stem diagramed. More small limbs and overgrown limbs were diagramed per log in this study than were in the studies mentioned earlier. The merchantable logs bucked from the tree stems were then hauled to a sawmill and processed into lumber. Individual log identity was maintained during this process to obtain the lumber grade volume sawn from each log.

A single expression for the quality of lumber sawn from each log was desired for evaluation of grading performance. Log value was used for this purpose. A set of 1969 lumber grade prices was used to compute a total value for the lumber produced from each log. The prices used are as follows:

B and Better Select	$357.52
C Select	351.74
D Select	277.72
Moulding	254.74
No. 3 Clear	196.95
No. 1 Shop	203.94
No. 2 Shop	159.86
No. 3 Shop	125.93
Nos. 1 and 2 Common	138.81
No. 3 Common	105.70
No. 4 Common	84.11
No. 5 Common	55.08

The objective was to establish comparable values for individual logs, not "real" values as would be used in appraisals.

A basic question was the relative effectiveness of alternate grading systems for estimating log value. In common usage, the value of logs in a grade is estimated with a regression or curve that recognizes diameter-value relationships. The effectiveness or accuracy of a grading system is related to the variability associated with the value estimates for each log grade.

A general model was used for evaluating the effectiveness of alternate log grading systems. The model involved fitting regressions of the form:

$$Y = a + b_1X + b_2X^2 + b_3X^3$$

in which

Y = value per thousand board feet of total lumber volume in the log ($/MLV), and

X = diameter of the log in inches.

The regressions were fitted to the logs of a given grade. The variance around the regression (first, second, or third degree polynomial) that best fit the logs in a grade was determined. The variances of the log grades in a system were pooled. The pooled variance furnished a measure of the proportion of the variability in $/MLV that could be attributed to log grade segregation and regression on diameter. This proportion was used as the criterion of accuracy for modifications of the improved system.

The model was used first to test the existing log grade system and establish a base to evaluate the performance of proposed modifications in the grading system. The existing grading system was applied to the study logs under two conditions. First, they were graded using the diagramed record of surface characteristics. This grade is assumed to be equivalent to grading log segments in the standing tree, as the diagrams contain a record of all the surface characteristics that could be seen in the standing tree.

The study logs were also visually graded in the mill yard by a regional check scaler. This is assumed to be equivalent to grading from diagramed records made in the mill yard. As such, this grading was done under conditions similar to those used to develop the improved grading system.

The statistical model was then used to test and compare modified versions of the existing system. The system was modified by defining various sizes of small limbs, limb stubs, and overgrown limbs as nondefects. Several increments of size were considered for overgrown limbs. Of these, 1 and 2 inches were selected for statistical evaluation. One size, one-half inch, was considered for limbs and limb stubs.

RESULTS

Lumber recovery and surface characteristic information was obtained for 426 logs. Their small end diameter ranged from 8 to 51 inches. The value per thousand board feet of total lumber volume in the logs ($/MLV) varied from $85 to $315. The distribution and variation of $/MLV with log diameter is shown by the scatter diagram in figure 2. A trend of increasing $/MLV with increasing log diameter is evident. The proportion of the variance of $/MLV that can be attributed to its regression on log diameter is 64 percent.

Performance statistics obtained from grading the sample logs under four different situations are shown in table 1. System 1 is the result of grading the diagramed

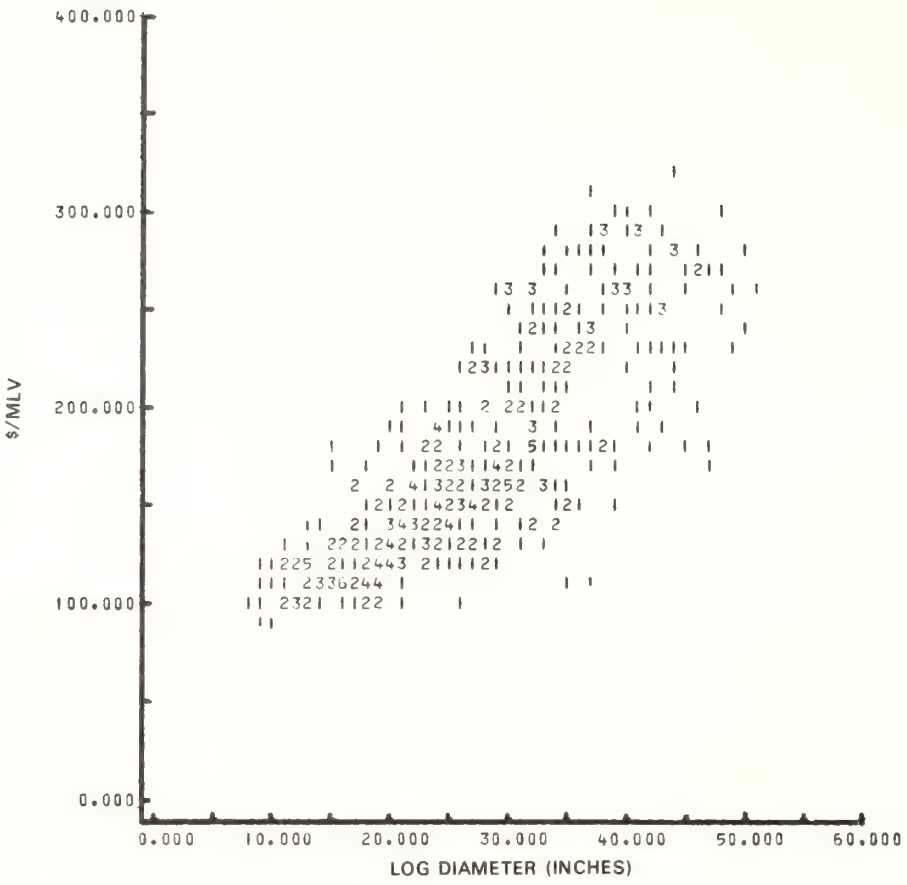

Figure 2.—Number of sample logs by 1-inch diameter and $10.00 $/MLV classes. Total number is 426.

records with the published system. System 2 results from the check scaler grading the logs in the mill log yard. System 3 results were obtained by grading the diagramed records with a modified grading system. In this grading system, overgrown limbs 1 inch or less in diameter and limbs and limb stubs one-half inch or less in diameter were not considered to be defects.[4/] In System 4, overgrown limbs 2 inches or less in diameter and limbs and limb stubs one-half inch or less in diameter were not considered to be defects.

The performance statistics indicate that the modified grading systems, Systems 3 and 4, perform as well as or better than the existing system. The proportion of the variance of $/MLV that can be attributed to grade segregation and regression on log diameter is larger, 79 and 80 percent for the modified system, as compared with 75 and 77 percent for the existing system.

[4] *Overgrown limb size is a measurement of the surface bark pattern and not a measurement of the original limb. The surface bark pattern expands with the tree growth, sometimes reaching more than twice the diameter of the original limb.*

Table 1.--*Performance statistics of four log grading system applications*

Log grade	Number of logs	Average		Significance of regression form[1/]			Proportion of variance in $/MLV attributable to grade segregation and regression on diameter (percent)
		Diameter (inches)	$/MLV)	First degree	Second degree	Third degree	
SYSTEM 1 - EXISTING GRADING SYSTEM APPLIED TO DIAGRAM RECORDS							
1	41	41.1	260.71	NS	NS	NS	--
2	60	35.7	233.02	**	NS	NS	--
3	72	32.8	207.83	**	NS	NS	--
5	253	22.6	141.90	**	NS	NS	--
Common							75
SYSTEM 2 - EXISTING GRADING SYSTEM APPLIED BY CHECK SCALER TO LOGS IN SAWMILL YARD							
1	78	38.6	252.48	**	**	NS	--
2	39	33.6	221.15	**	NS	NS	--
3	54	32.1	201.95	**	NS	NS	--
5	255	22.9	142.39	**	NS	NS	--
Common							77
SYSTEM 3 - MODIFIED GRADING SYSTEM APPLIED TO DIAGRAM RECORDS OVERGROWN LIMBS ≤ 1 INCH ARE NOT PRIMARY DEFECTS LIMBS ≤ ONE-HALF INCH ARE NOT PRIMARY DEFECTS							
1	77	37.3	247.81	**	**	NS	--
2	71	34.2	223.13	**	NS	NS	--
3	49	30.4	182.94	**	NS	NS	--
5	229	22.3	138.20	**	NS	NS	--
Common							79
SYSTEM 4 - MODIFIED GRADING SYSTEM APPLIED TO DIAGRAM RECORDS OVERGROWN LIMBS ≤ 2 INCHES ARE NOT PRIMARY DEFECTS LIMBS ≤ ONE-HALF INCH ARE NOT PRIMARY DEFECTS							
1	104	36.7	245.40	**	**	NS	--
2	66	32.9	206.31	**	NS	NS	--
3	35	29.7	179.23	*	NS	NS	--
5	221	22.0	136.30	**	NS	NS	--
Common							80

[1/] ** Significant at the 1-percent level.
* Significant at the 5-percent level.
NS Not significant.

Regression curves of $/MLV on log diameter for the log grades in each grading system are shown in figure 3. Note the similarity between Systems 2, 3, and 4.

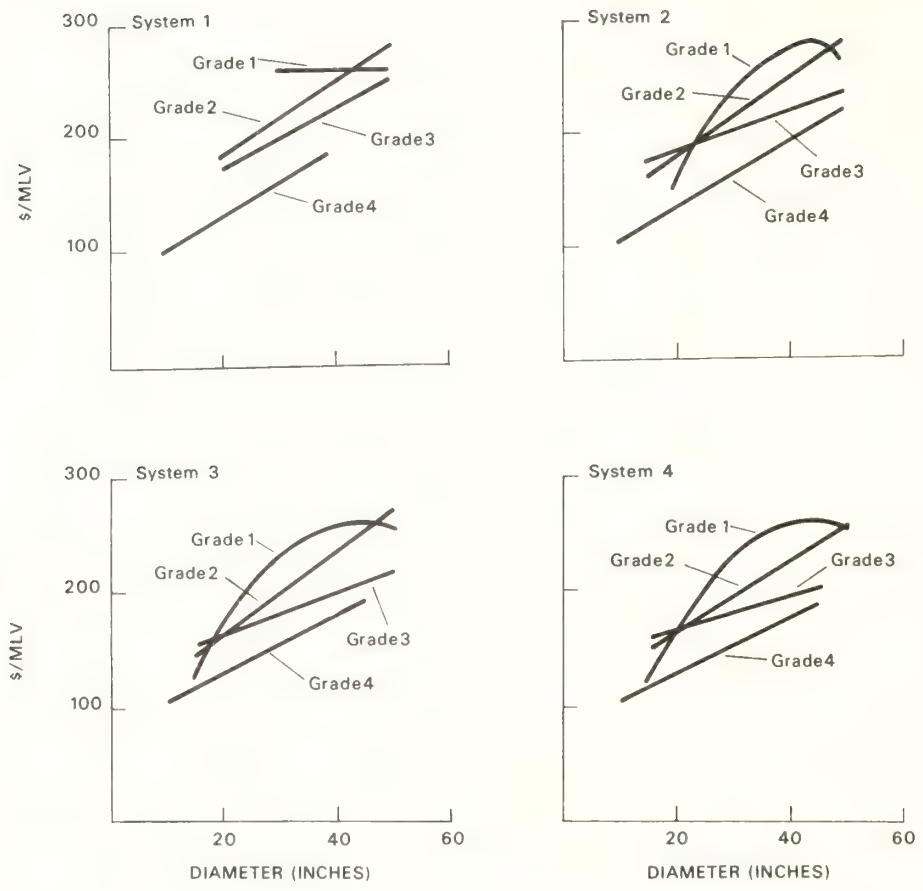

Figure 3.—Regression curves of $/MLV on log diameter for the log grades in four grading systems.

CONCLUSIONS

The study results indicate that the grading specifications for the existing system for grading sugar pine saw logs in trees can be modified without reducing the performance of the system. In fact, it appears that modification would improve the accuracy of estimates of log $/MLV. Either System 3 or System 4 allows a grader to ignore problem surface characteristics. In terms of estimating $/MLV accurately, they appear to be almost equal.

Several factors should be considered in making a choice between Systems 3 and 4. The 1-inch allowance for overgrown limbs in System 3 is more closely alined with the application problems reported by graders. They have had difficulty with the smaller overgrown limbs. Field application tests of Systems 3 and 4 would help resolve this point. The use of existing lumber recovery data is another consideration. It would be desirable to modify the existing system and retain the use of the associated performance data. The performance characteristics of System 3 are more similar to System 2 than those of System 4. For these reasons System 3 appears to be the better of the two modifications.

GPO 985-938

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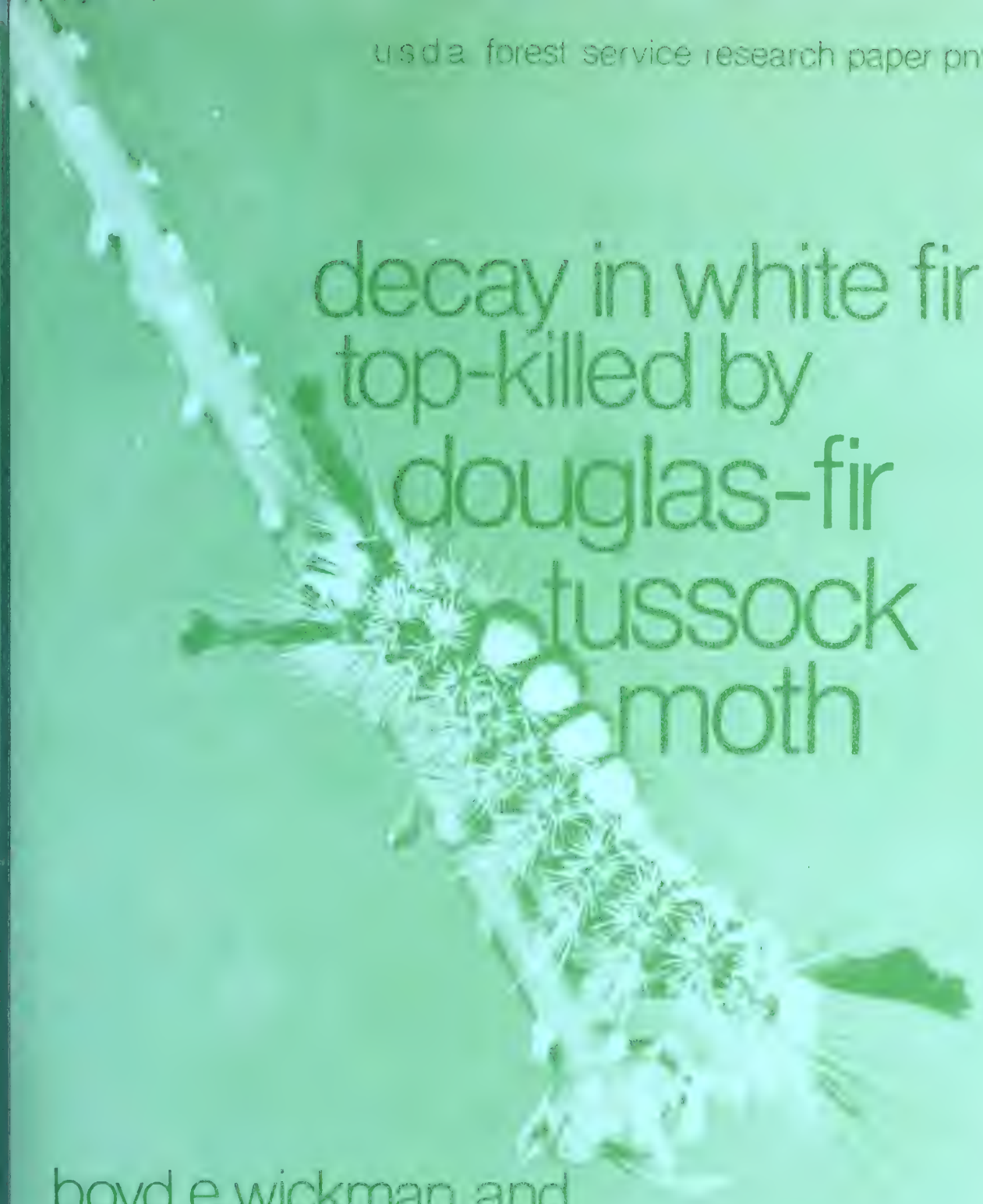

decay in white fir top-killed by douglas-fir tussock moth

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ABSTRACT

Stands heavily defoliated in 1936-37 by the Douglas-fir tussock moth, *Hemerocampa pseudotsugata* McD., at Mammoth Lakes, California, were studied to determine the incidence and extent of decay in top-damaged trees. This was done by dissecting the tops of trees felled during logging. Comparisons were made with white fir in a nearby logged area that was not defoliated during the old outbreak. Few decay organisms were isolated from trees top-killed by Douglas-fir tussock moth. However, old top damage and a condition known as wetwood were common in the infested area. Wetwood was found in 17 of 21 top-damaged trees in the infested area and in one of 50 trees in the uninfested area. We conclude, therefore, that in east-side Sierra Nevada white fir stands, the threat of defect is not economically serious in large trees that will be logged within 35-40 years after top damage.

Keywords: Wood decay, Douglas-fir tussock moth, *Hemerocampa pseudotsugata*, wood destroying fungi.

INTRODUCTION

One of the earliest recorded and studied outbreaks of Douglas-fir tussock moth, *Hemerocampa pseudotsugata* McD., on white fir (*Abies concolor* [Gord. & Glend.] Lindl.) occurred at Mammoth Lakes, California, from 1934 to 1938. A 5-acre plot was established there in 1937 to study the effects of defoliation. The tree damage resulting from this infestation and a later one on the Stanislaus National Forest in California consisted of mortality, growth loss, and top-kill (Wickman 1963). Heavy defoliation by the tussock moth can result in 12 percent of a stand being top-killed. The long-term effects of this damage have not been determined, but balsam firs top-killed by spruce budworm defoliation were found to have a high incidence of decay (Stillwell 1956). Decay fungi entering through dead tops of pole-sized white firs defoliated by tussock moth could result in timber losses from heart rot at the time of harvest.

A 1970 timber sale on the Mammoth Lakes District, which included part of the 1937 infestation and study area, offered an opportunity to determine if heart rots were a significant cause of defect in white fir trees 33 years after top-killing by the Douglas-fir tussock moth. Many of the pole-sized trees top-killed as a result of the severe defoliation are now of merchantable size and were included in the timber sale.

Our objectives were to investigate the pathological-entomological relationships of white fir top-killed by tussock moth. Specifically, we wanted to determine the presence and identity of wood destroying fungi, the extent of decay in trees with and without top-kill, and finally the amount of cull in top-killed trees as a result of decay.

METHODS

The study area is located on the Inyo National Forest on the east side of the Sierra Nevada several miles north of the Mammoth Lakes Ranger Station at about 8,000 feet elevation (fig. 1). The mixed conifer stand is composed mainly of white fir and Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.), but also contains scattered red fir (*Abies magnifica* A. Murr.) and lodgepole pine (*Pinus contorta* Dougl.). Many of the old-growth white fir were killed by secondary insects shortly after the infestation. In 1945 the area was logged for old-growth pine and any remaining old fir. The first relogging of the area began in spring of 1970. The logged trees sampled were 14 to 38 inches d.b.h. and 75 to 150 years old.

Figure 1.—Mammoth Lakes, California, Douglas-fir tussock moth plot area. Site of 1934-37 infestation (looking north from Sawmill Summit).

The 5-acre study plot was located in an old 1,000-acre infestation area, and

top-killed trees were measured on this plot. A nearby noninfested to lightly infested area[1/] included in the 1970 timber sale was used as a check. Wood samples were taken from trees with (1) spike tops, (2) bayonet, forked, or crooked tops (indicating an old buried leader), and (3) normal tops.

The trees on the old tussock moth plot were felled by the timber sale contract logger. His crews bucked the trees into 16-foot logs and also cut extra disks for us in the top portion. We followed the loggers and measured extent of decay and amount of cull by cutting a series of disks down the log from the point of initial top damage (fig. 2). We used Stillwell's (1956) method of recording data for later tabulation so we could make comparisons with his work on balsam fir top-killed by spruce budworm.

Figure 2.–Cutting samples from injured tops to determine the extent of decay.

[1/] *As determined from old insect survey maps and growth ring analysis.*

Deformed tops were carefully examined to insure that the damage was a result of tussock moth defoliation. This was done by cutting disks immediately above, below, and at the point of leader damage and taking the ages at each cut. If the damage was due to defoliation or secondary insect attack, the upper disk had 27 to 32 annual rings; the lower disk, 29 to 34 annual rings; and the damaged disk contained the buried dead leader in the case of bayonet, forked, and crooked tops and had no more than 33 annual rings (fig. 3). Trees suffering top-kill before 1936 or after 1942 were not included in the decay determinations.

Data on the incidence of decay entering spike tops killed by fir engraver beetles, *Scolytus ventralis* (Lec.), were taken if the beetles had top-killed trees within 5 years after the tussock moth defoliation (fig. 4). Studies have shown that trees weakened by defoliation are susceptible to beetle damage for several years after defoliation stops (Wickman 1963). All felled trees with apparently undamaged tops were also checked (fig. 5).

Sample disks were put in plastic bags, taken to the laboratory and stored at 3° C. All isolations were made within 1 week after collection.

Several wood chips were taken from within each of the sample disks by splitting them. They were surface sterilized in 0.1 percent sodium hypochlorite for 15 minutes, placed in petri dishes containing 2 percent malt agar and 100 p.p.m. streptomycin sulfate, and incubated at 20° and 25° C. for several weeks. During the period of incubation, fungi growing from the chips were hyphaltipped and grown in pure culture on 2 percent malt agar slants for identification. Decay organisms were identified by comparing the isolates with

Figure 3.—A, Bayonet tops resulting from Douglas-fir tussock moth defoliation contain buried leaders.

Figure 3.—B, Forked tops resulting from Douglas-fir tussock moth defoliation contain buried leaders.

Figure 3.—C, Crooked tops resulting from Douglas-fir tussock moth defoliation contain buried leaders.

Figure 4.—Spike top tree damage caused by fir engraver beetle attacks after tops were severely defoliated by Douglas-fir tussock moth with Fomes pinicola *decay fungi. A, Top-killed in 1942; B, top section showing longitudinal extent of decay column; C, diameter of decay column was 8 inches.*

Figure 5.–Normal white fir tops, evidently only lightly defoliated during the tussock moth infestation, suffered no top-kill.

known pure culture of decay fungi in California and by using Nobles' (1948) methods and key to identify wood decay fungi.

RESULTS

Dissection and examination of trees with damage resulting from tussock moth defoliation failed to show the presence of typical decay. Field observations suggested that a high proportion of the trees with damaged tops had incipient decay in the living bole at the point of old top-kill. The presence of decay organisms was not confirmed in the laboratory, however. Only two of 21 top-damaged trees contained any decay fungi as indicated by laboratory isolation and identification (table 1). In both cases, *Fomes pinicola*, a common brown rot fungus, was present. In one tree sufficient rot was present to cull the top log. In the other tree no advanced decay was present, and the rot organism was isolated from wood chips taken at the point of top-kill.

The brown discoloration occurring in the central core of the living bole and resembling incipient decay was determined to be a commonly occurring discoloration of white fir wood known as "wetwood" (fig. 6). Wetwood in white fir is a physiological condition of unknown cause that

Figure 6.–Wetwood–dark stained area in the center of the cross section and to the right of the buried leader.

Table 1.--*Top damage as a result of [illegible] and fir engraver attacks, 1936-42, at Mammoth Lakes, California*

Tree number	Diameter at stump (inches)		Total height (feet)	Length of top-kill or new leader (feet)	Dead leader			Longitudinal extent of wetwood below base of dead leader (feet)
	1970	1936			Diameter (inches)	Age (years)	Year of death	
			DEAD SPIKE TOP (killed by fir engraver beetles)					
1	30	23	65	15	6	32	1938	16
2	18	14	60	20	8	34	1940	6
3	22	16	65	20	10	(1/)	1942	8 (decay) 2/
4	18	14	60	20	8	(1/)	1941	8
			LIVE BAYONET, FORKED, OR CROOKED TOP (buried leader)					
5	24	9	60	30	2	10	1938	--
6	32	21	95	25	4	24	1936	1
7	35	29	112	12	3	6	1940	2
8	23	13	80	40	4	40	1939	6
9	22	10	60	30	4	42	1937	1
10	24	16	90	20	2	32	1938	3
11	22	14	85	20	1	5	1937	--
12	30	22	90	20	3	20	1940	3
13	14	8	40	20	2	29	1938	4 (decay) 3/
14	23	15	65	15	1	4	1936	--
15	19	13	75	15	1	8	1938	1
16	18	8	55	15	1.5	6	1938	1
17	18	12	65	15	4	33	1938	10
18	18	9	70	10	1.5	12	1938	1
19	30	22	105	20	4	38	1939	2
20	17	12	65	10	1	(1/)	1936	--
21	32	22	90	15	2	10	1937	1
			NORMAL TOP					
22	30	20	105	--	--	--	--	--
23	24	20	95	--	--	--	--	--
24	30	24	115	--	--	--	--	--
25	15	10	70	--	--	--	--	--
26	22	14	90	--	--	--	--	--
27	37	29	115	--	--	--	--	--
28	32	26	105	--	--	--	--	--
29	18	12	70	--	--	--	--	--
30	22	14	75	--	--	--	--	--
31	16	12	60	--	--	--	--	--
32	24	16	90	--	--	--	--	--
33	33	27	110	--	--	--	--	--

1/ Could not be determined.

2/ 16 feet of cull.

3/ Extends 2 feet above base of dead leader.

appears in association with a particular species of bacterium (Wilcox and Schlink 1971). Wetwood, however, is most common in the lower bole of white firs and not usually found in the upper bole unless associated with injuries (Wilcox and Pong 1971).

Table 1 shows that of the trees with dead or damaged tops, 17 of 21 had wetwood in the living bole at the point of old top-kill. We also observed wetwood in six of 14 trees at a point 3 feet below the old injury. Three of 14 trees had wetwood in the merchantable top, and only one tree had wetwood extending into the new leader.

Of the white firs with no old damage or top-kill (this included 50 trees in the check area), only one of 57 trees had wetwood in the upper bole. In this particular case, old patch killing by fir engraver beetles was observed on the living top. There was also one cull top log, with defect due to decay, left by the loggers in the check area.

DISCUSSION

Stillwell (1956) found a higher incidence of decay in balsam fir top-killed as a result of spruce budworm defoliation than we found in white fir similarly damaged by tussock moth. He predicted that trees with tops killed back to a diameter greater than 0.5 inch and older than 5 years will eventually contain some decay. In our study, trees with tops killed up to 8 inches in diameter were free of decay. The only tree in our study with appreciable advanced decay was one with a 10-inch diameter dead top killed by fir engraver beetles.

In trees with buried leaders we found wetwood columns extending 1 to 10 feet in the tops, whereas Stillwell found decay columns 1 to 23 feet in the tops with many 8 to 10 feet in length. These discrepancies are most likely due to differences in insects, diseases, hosts, and local climate. For instance, Basham (1971) found no significant heart rot in eastern white pine (*Pinus strobus* L.), as a result of top-damage by the weevil (*Pissodes strobi* Peck). The weevil-caused top-damage occurred 16 to 20 years before the sample was taken and consisted of stem crooks containing buried leaders. Basham further predicted that it was unlikely that decay would form in these top-damaged trees.

Also, the climate of the Mammoth Lakes area is a factor that limits the occurrence and rate of decay. In this region of high elevation, short growing season, and low rainfall (about 28 inches annual precipitation, much of which is snow) the growth of decay fungi and development of heart rot are quite slow. On the other hand, in the coastal areas of northern California where temperature and moisture conditions are more favorable for decay fungi, broken and dead tops of white fir are considered a cull factor in marking timber (Kimmey 1950).

Another factor that may have limited the incidence of decay was the absence of heartwood in killed tops. Unpublished studies by Wilcox indicate that in a sample of white fir from the northern Sierra Nevada the average sapwood thickness was about 6 inches and the average number of annual rings in sapwood about 48. Thus, unless rather large tops are killed, decay fungi do not have direct access to heartwood and may be restricted in development by the sapwood.

The common occurrence of wetwood in association with dead tops is not fully understood. Perhaps dead tops provide entrance for the particular bacteria that bring about the wetwood condition, but wetwood is not confined to tops of merchantable size trees. We cut down three sapling-sized top-damaged trees (4, 8, and 10 inches d.b.h.), aged 55, 65, and 78 years, and found that two of the trees had their terminal shoots killed by the tussock moth. Both trees had extensive wetwood in the heart extending to the base of the tree. This condition has been found in almost all small trees top-damaged by the Douglas-fir tussock moth.

Canadians have also found an association of butt rot in balsam fir defoliated by spruce budworm, apparently caused by high rootlet mortality (Sterner 1970). Our examinations did not reveal a similar condition in white fir at Mammoth Lakes, but it might be a factor in other stands damaged by the Douglas-fir tussock moth.

The study revealed the importance of considering the insect-disease interrelationships in measuring growth impact and mortality in forest stands. Very often

the economic damage caused by one type of organism, whether pathogen or insect, can be traced to a condition caused by another type of organism. To understand the total losses from forest pests, this integrated insect-disease approach is often needed.

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Lumber Yield From Sitka Spruce In Southeastern Alaska

OCT 24

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ABSTRACT

A representative sample of 400 mature, Sitka spruce, sawtimber trees from throughout southeastern Alaska produced 1,009 commercial saw logs that were sawn at Wrangell, Alaska. The distribution of these saw logs by log grade was: 3 percent Select, 7 percent No. 1, 43 percent No. 2, and 47 percent No. 3. The total net log scale (Scribner) was 774,000 board feet. A total of 1,051,000 board feet of lumber were produced from the sample logs, most of which (98 percent) were cants 3 to 8 inches in thickness for export to Japan.

The lumber was graded and tallied by two lumber grading systems: (1) Export grades used by the sawmill, and (2) the lumber grading and dressing rules used by the Pacific Lumber Inspection Bureau (PLIB).

Under the Export grading rules, the average yield of high grade cants (Piano grade) was 9 percent. The comparable yield by the PLIB lumber grades was 13 percent for No. 2 and No. 3 Clear.

: Log yield, lumber, forest industries, Sitka spruce, southeast Alaska.

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INTRODUCTION

Southeastern Alaska contains an estimated 68 billion board feet of old-growth Sitka spruce (*Picea sitchensis* (Bong.) Carr.) timber.[1] During the past 20 years, there has been a tenfold increase in the use of this resource for lumber and pulp and a shift from the production of boards to thicker export cants. Since the early 1960's, most of this increase in timber production has been exported to Japan. In 1963, about 43 million board feet of Sitka spruce lumber was exported to Japan--in 1970 this volume had increased to 219 million board feet.[2]

Most of the Sitka spruce sawtimber harvested in southeastern Alaska is cut from National Forest lands. Before it can be exported, this timber must receive primary manufacturing in accordance with an act of the U. S. Congress.[3] Primary sawmill manufacturing is defined by the U. S. Forest Service as the log breakdown process wherein logs are reduced in size by sawing to the extent that the residual cants, slabs, or planks do not exceed a nominal 8 inches in thickness.[4]

The lumber market for mills in southeastern Alaska is primarily an export cant market. A small amount is sold for local consumption, and an occasional shipment of the higher-grade boards, produced incidentally to cant manufacture, is shipped to domestic markets outside Alaska. The production of lumber for domestic use outside Alaska is restricted by the lack of economic transportation facilities.

To reflect this major shift from the production of typical shop, dimension, board, and clear lumber items[5] to the manufacture of primarily export cants, a recovery study was made by the Pacific Northwest Forest and Range Experiment Station, U. S. Forest Service, in cooperation with the Wrangell Lumber Company, Wrangell, Alaska.

This report describes the study objectives, procedures, and the results of sawing a sample of typical old-growth Sitka spruce according to current manufacturing practices in southeastern Alaska.

OBJECTIVES

The main purpose of the study was to determine the kind and volume of lumber that would be produced under current industrial manufacturing practices from the various grades and sizes of Sitka spruce logs available to sawmills in southeastern Alaska. This up-to-date lumber yield information was needed by the public agencies and the timber industry to provide a better basis for appraising timber and for evaluating the quality of Sitka spruce sawtimber, particularly that on the Tongass National Forest.

Specific timber quality and yield data were also obtained by the Pacific Northwest Forest and Range Experiment Station for the purpose of developing a tree grading system for Sitka spruce.

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[1] O. Keith Hutchison. Alaska's forest resource. Portland, Oreg., Pac. Northwest Forest & Range Exp. Stn., USDA Forest Serv. Resour. Bull. PNW-19, 74 p., illus., 1967.

[2] David R. Darr. Production, prices, employment, and trade, fourth quarter 1970. Portland, Oreg., Pac. Northwest Forest & Range Exp. Stn., USDA Forest Serv., 57 p., illus., 1971.

[3] U.S. Congress Act of April 12, 1926, exportation of timber (44 Stat. 242; 16 U.S.C. 616).

[4] USDA Forest Service. Export and primary manufacture policy, National Forests of Alaska. *In* Forest Serv. Manual, sect. 2410.3–1, Reg. 10 suppl. 1969.

[5] Lester J. Sullivan and John F. Shields. Lumber grade recovery from old-growth Sitka spruce on the South Tongass National Forest. Mimeogr. rep., USDA Forest Serv., Juneau, Alaska, 1958.

An investigation of lumber prices to augment the yield information was beyond the scope of the study. Reliable and current information on the value of cants in Japanese markets is not generally available, particularly with respect to detailed prices by cant grades and sizes. Possible sources of general information on prices include the U. S. Treasury Department, Bureau of Customs; the University of Alaska at Fairbanks; and the State of Alaska Department of Commerce, Juneau. The Bank of Japan, Tokyo, is also a possible source of cant price information.

PROCEDURES

TIMBER SAMPLE

A sample was selected of about 400 trees, as representative as possible of the full range of size and quality of commercial sawtimber in southeastern Alaska. The trees were obtained from 18 widely distributed logging operations on the North and South Tongass National Forests as shown in figure 1. The timber stand in each of these locations was considered typical of the timber in that particular area. Within each designated area, individual sample trees were selected on the basis of six tree size classes and three stem quality classes. Approximately the same number of trees were selected in each size-quality grouping.

The total sample was not intended to be representative of a typical log mix for any particular sawmill. For example, some of the poorer quality or smaller logs included in the study might have normally been processed for pulp. The objective, as previously stated, was to obtain adequate saw log recovery information for the full range of size and quality of timber available in southeastern Alaska.

LOGGING, TRANSPORTATION, AND SCALING

The sample trees were selected, logged, and sawn in two approximately equal groups. The first group was logged and sawn in 1965, the other in 1967. This interruption was necessary because of major alterations required in the log and lumber storage facilities at the Wrangell mill. For each group of trees, the procedure for selection, logging, and sawing was identical.

The study trees were felled and bucked into saw logs by the cooperating logging contractors according to normal industry practice in southeast Alaska. Each log was tagged in the woods to identify its origin with respect to sample area, tree, and position in the tree. The logs from each area were then assembled into rafts and towed to the Wrangell mill for storage, scaling, and grading prior to sawing. The Puget Sound Log Scaling and Grading Bureau graded and scaled all study logs in the mill storage pond according to Bureau rules.[6]

Some 400 sample trees produced 1,009 merchantable logs. Tables 1 and 2 show the distribution of the study logs by log grade, length, and scaling diameter. Three percent of all study logs were Select grade, 7 percent No. 1, 43 percent No. 2, and 47 percent No. 3 grade logs.

SAWING

The study logs were sawn under normal production conditions at the Wrangell Lumber Company mill, Wrangell, Alaska. Mill production equipment included a single-cut bandsaw, edger, and a 40-foot gang trimmer. Logs longer than 40 feet were bucked before sawing to accommodate the mill equipment.

[6] Official log scaling and grading rules for the Puget Sound Log Scaling & Grading Bureau, Tacoma, Washington, January 1, 1969.

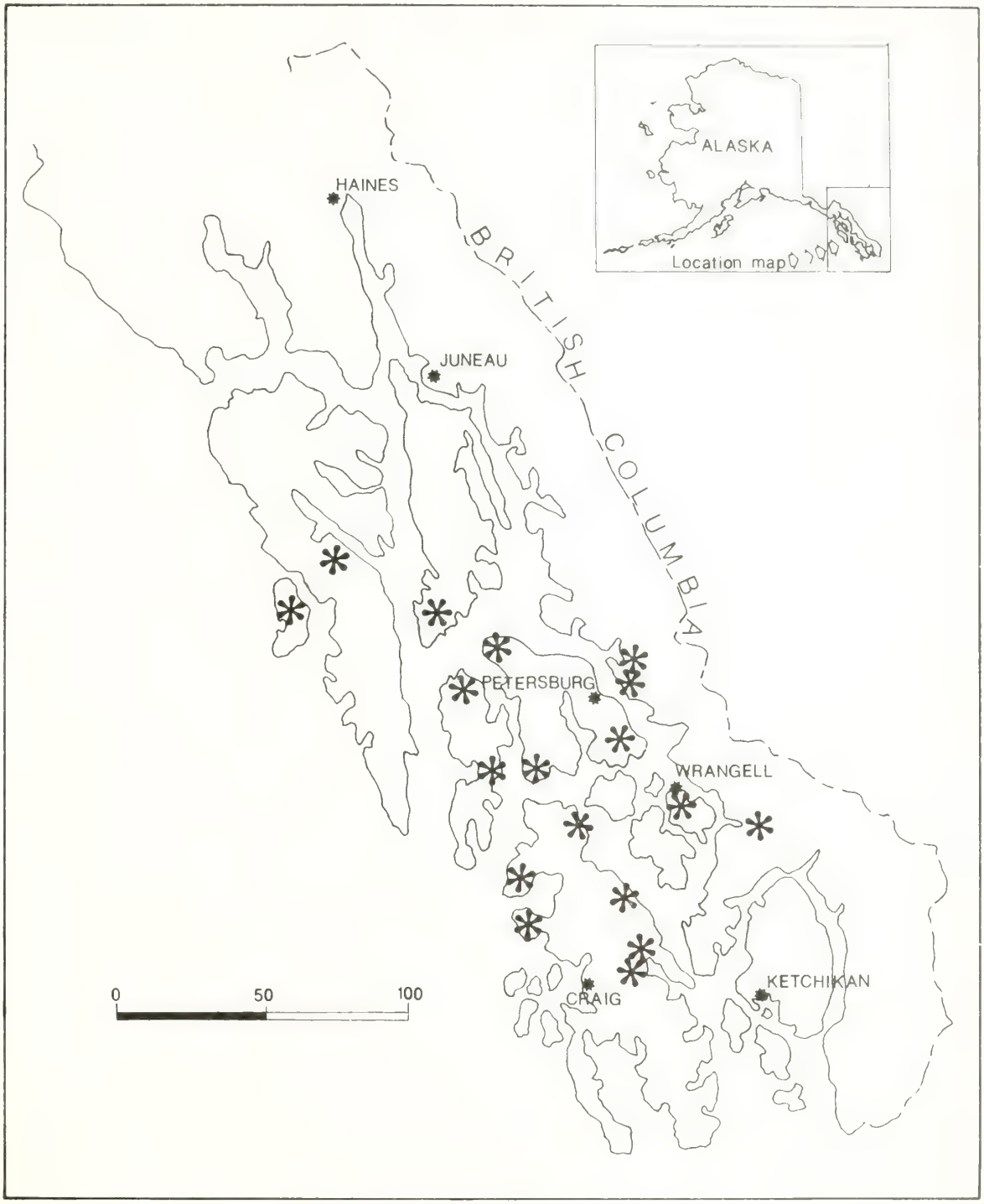

Figure 1.–Approximate location of the 18 sample areas.

Table 1.—The distribution of study logs by length[1] and grade[2]

Log length (feet)	Select	No. 1	No. 2	No. 3	All grades
			Number		
12	--	--	1	1	2
14	--	--	2	2	4
16	--	--	2	9	11
18	--	--	--	10	10
20	--	--	3	13	16
22	--	--	2	9	11
24	6	5	23	23	57
26	6	8	19	28	61
28	--	2	11	19	32
30	7	5	19	21	52
32	1	6	45	64	116
34	4	9	21	20	54
36	--	3	27	33	63
38	--	--	3	15	18
40	3	24	108	69	204
42	--	--	15	18	33
44	--	--	41	29	76
46	--	--	8	9	17
48	1	4	81	72	158
50	--	--	5	8	13
52	--	--	--	--	--
54	--	--	--	1	1
Total	28	72	436	473	1,009

1/ Woods-length logs. Logs longer than 40 feet were bucked at the mill to shorter lengths for sawing.

2/ As determined by the Puget Sound Log Scaling and Grading Bureau in the mill pond for woods-length logs.

In accordance with study objectives, the logs were cut to recover the optimum value of each log, consistent with the company's normal manufacturing procedures for producing mainly rough green cants for export to Japan (fig. 2). About 98 percent of the lumber volume produced was in cants 3 to 8 inches in thickness; and 0.7 percent was manufactured into ship stanchions, 9 and 10 inches in thickness. Less than 2 percent was manufactured into 2-inch dimension and 1-inch boards and graded under West Coast Lumber Inspection Bureau (WCLIB) rules.

During the sawing, each piece of lumber was identified by log and tree.

LUMBER GRADING

All cants (98 percent of the study lumber) were graded by two different grading systems. In this report these systems are designated as:

1. PLIB
2. Export

The PLIB grades were based on the export grading and dressing rules for

Table 2.—The distribution of study logs[1] by scaling diameter and grade

Log diameter (inches)	Select	No. 1	No. 2	No. 3	All grades
			Number		
6	--	--	--	12	12
7	--	--	--	28	28
8	--	--	--	35	35
9	--	--	--	40	40
10	--	--	--	34	34
11	--	--	--	39	39
12	--	--	--	54	54
13	--	--	--	52	52
14	--	--	17	24	41
15	--	--	25	21	46
16	--	--	27	14	41
17	--	--	19	13	32
18	--	--	37	14	51
19	--	--	24	10	34
20	--	--	20	7	27
21	--	--	30	8	38
22	--	--	25	7	32
23	--	--	24	8	32
24	--	1	21	5	27
25	--	3	20	11	34
26	--	3	12	6	21
27	--	7	10	4	21
28	--	7	11	5	23
29	--	6	15	1	22
30	2	8	12	2	24
31	--	5	7	3	15
32	2	1	6	1	10
33	1	4	7	2	14
34	1	2	8	2	13
35	4	1	5	--	10
36	--	--	2	1	3
37	--	1	4	2	7
38	1	2	8	1	12
39	--	1	5	1	7
40	2	2	6	1	11
41	2	2	1	--	5
42	2	3	5	--	10
43	--	--	3	--	3
44	--	1	5	1	7
45	2	1	2	--	5
46	1	1	5	--	7
47	1	1	1	--	3
48	1	1	1	1	4
49	2	2	1	2	7
50	--	1	--	--	1
51	1	--	2	--	3
52	--	1	1	--	2
53	2	2	--	--	4
54	--	--	1	1	2
55	1	1	--	--	2
56	--	1	1	--	2
Total	28	72	436	473	1,009

1/ Woods-length logs. Logs longer than 40 feet were bucked at the mill to shorter lengths for sawing.

Figure 2.–Study cants being graded and tallied on green chain.

Sitka spruce, R List 1951, of the Pacific Lumber Inspection Bureau, Seattle, Washington, and the West Coast Lumber Inspection Bureau Rule No. 15.[7] A PLIB grading supervisor applied the following cant grades under these rules: No. 2 Clear, No. 3 Clear, Select Merchantable, No. 1 Merchantable, No. 2 Merchantable, No. 3 Common, Factory Select, No. 1 Shop, No. 2 Shop, and No. 3 Shop. The PLIB grader "pencil trimmed and ripped" many large cants with wane to establish their appropriate PLIB grade.

The Export grades applied to the study lumber were designated as Piano, A, B, and C. These grade classifications were used by the Wrangell Lumber Company for cants exported to Japan. They were based primarily on confidential contract agreements between the company and the purchasers and no written specifications for the grades were available. A company grader applied these four export classifications to all study cants. As with PLIB grades, some cants were pencil ripped and trimmed to establish the export grades.

The minor amount (about 2 percent) of 2-inch dimension and 1-inch lumber produced with Export grades was graded under the West Coast Lumber Inspection Bureau Rule No. 15.

CUBIC VOLUME: LOGS, CHIPS, AND SAWDUST

In addition to the lumber grade and board-foot-volume data collected, the cubic volume of the logs, lumber, chippable residue, and sawdust was calculated for all study logs.

[7] Standard grading and dressing rules for Douglas-fir, west coast hemlock, Sitka spruce, and western red cedar lumber, No. 15, West Coast Lumber Inspection Bureau, Portland, Oregon, 1956.

The gross cubic log volume was computed by the following formula:

$$\text{Gross cubic log volume} = \frac{\pi L (D_s^2 + D_s D_1 + D_1^2)}{12}$$

where

D_s is the log scaling diameter, small end

D_1 is the log scaling diameter, large end

L is the log length.

The sawdust volumes were calculated by using an average saw kerf of 0.25 inch and the computed surface area of the lumber from each log.

The chippable residue volume was calculated by subtracting the lumber and sawdust volumes from the gross cubic log volume. This includes a small amount of sawdust produced from slabs, edgings, and trim ends.

SUMMARY OF RESULTS

A significant[8] difference in the average lumber recovery percent[9] was found among the four log grades as shown in table 3.

The differences in lumber tally volumes between the PLIB and Export grades in table 3 are primarily because of pencil trimming and ripping necessary to establish grade.

A significant linear relationship was found between lumber recovery and the log scaling diameter when all study logs were considered as a group, as shown in figure 3.

[8] Statistically significant at the 1-percent level; covariance analysis.

[9] The ratio of lumber tally to net log scale in percent (overrun).

Table 3.—Lumber recovery by log grade

Log grade	Number of logs	Net log scale	PLIB		Export	
			Lumber tally	Recovery	Lumber tally	Recovery
		Board feet		*Percent*	*Board feet*	*Percent*
Select	28	57,410	70,712	123.2	71,923	125.3
No. 1	72	122,060	145,355	119.0	147,443	120.8
No. 2	436	440,260	564,556	128.2	588,773	133.7
No. 3	473	154,480	224,701	145.4	243,023	157.3
All grades	1,009	774,210	1,005,424	129.9	1,051,162	135.8

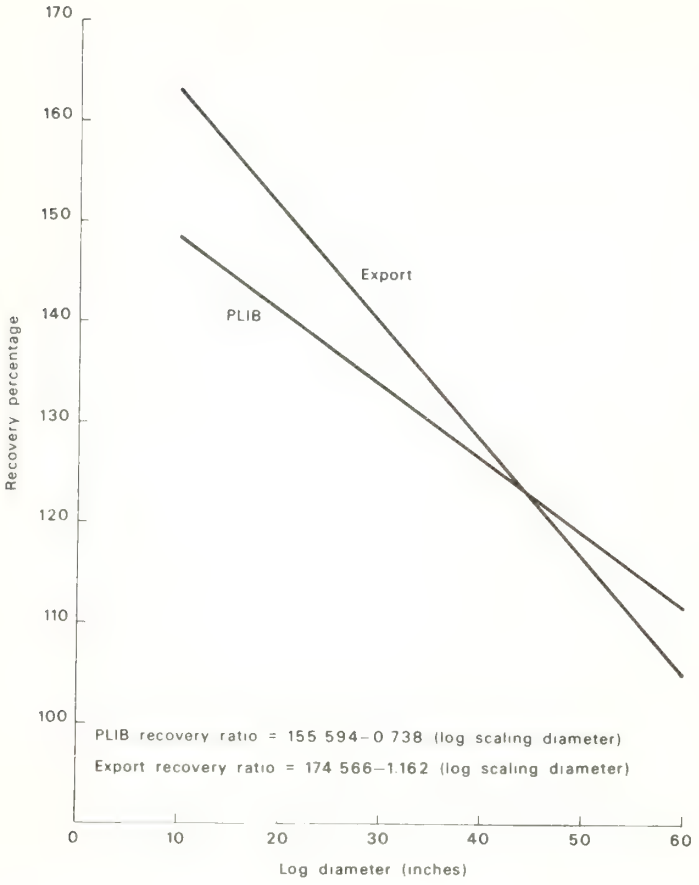

Figure 3.—The relationship of lumber recovery percent to log diameter for PLIB and Export lumber grades.

The average lumber grade yield for each log grade is shown in figures 4 and 5 for PLIB and Export grades.

The detailed lumber yield, chippable residue, and sawdust volume according to log size and log grade are shown in appendix I for the PLIB grades (tables 4 through 23) and in appendix II (tables 24 through 43) for the Export grading system.

EXPORT YIELD COMPARED WITH PLIB

The transient and confidential nature of the Export lumber grades makes it difficult, if not questionable, to compare the lumber yields by these classifications with the PLIB grades which are recognized as an industrial standard. However, recognizing the limitations of the Export grade data, such a comparison was made for the cants produced from all study logs (all log grades). The results are summarized in figure 6.

As illustrated in figure 6, 77 percent of the volume in Export Piano grade was graded under PLIB as No. 2 and No. 3 Clear; 18 percent as PLIB Factory Select; 3 percent No. 1 Shop; Select Merchantable accounted for the remaining 2 percent.

For the Export A cants, 24 percent was No. 1 Shop; 20 percent Select Merchantable; 14 percent Factory Select; 12 percent No. 1 Merchantable; 10 percent No. 2 Merchantable; and 8 percent No. 2 and No. 3 Shop. Other PLIB grades accounted for the remaining 12 percent.

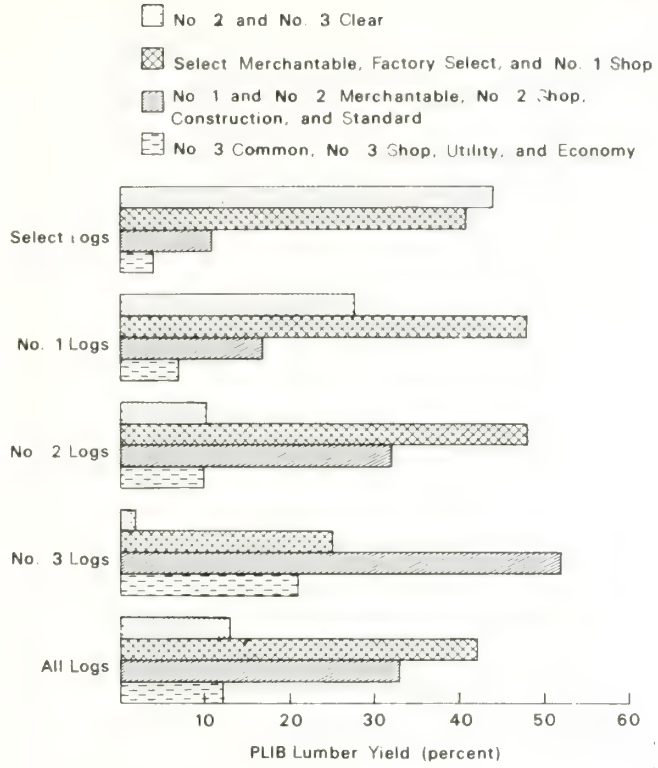

Figure 4.—Average yields of PLIB lumber grade groups for each log grade and all logs.

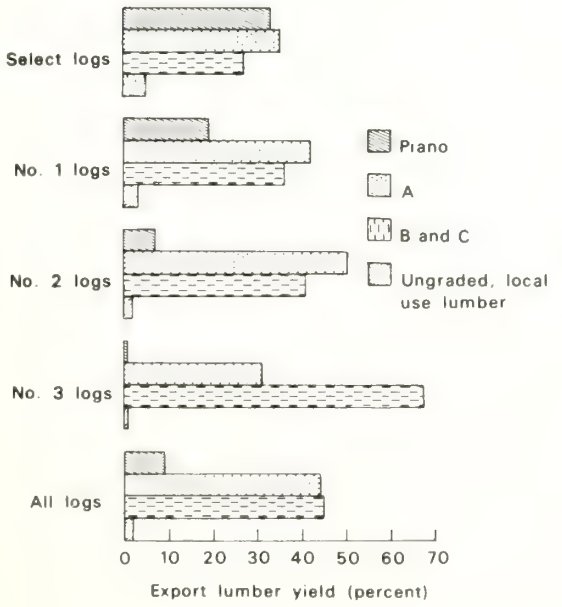

Figure 5.—Average yields of Export lumber grade groups for each log grade and all logs (including small amount of ungraded lumber for local use).

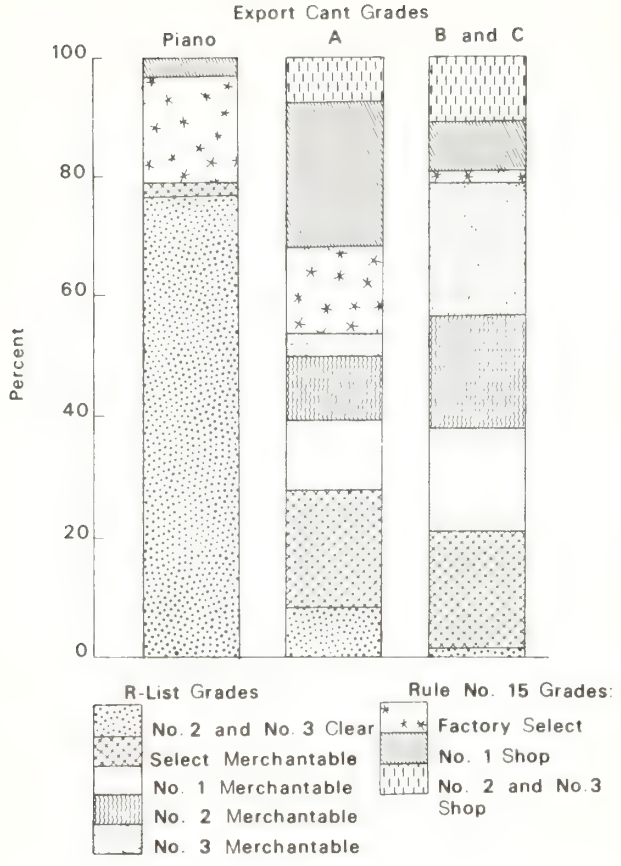

Figure 6.--A comparison of the PLIB and Export grades for all study logs.

For the Export B and C grades combined, 22 percent of the volume graded PLIB No. 3 Common; 19 percent Select Merchantable; 19 percent No. 2 Merchantable; 17 percent No. 1 Merchantable; 8 percent No. 1 Shop, and the remaining 15 percent in other PLIB grades.

APPENDIX I

TABULAR LUMBER YIELD DATA

by

PLIB Grades

Table 4.—Summary of log scale, PLIB lumber tally, and cubic volumes by diameter classes—Select logs

Log diameter (inches)	Number of logs	Log scale[1]		PLIB lumber tally		Cubic volume				
		Gross	Net	Volume	Recovery ratio[2]	Log	Lumber	Lumber recovery ratio[3]	Sawdust	Chippable residue
						Cubic feet				
20	2	3,060	2,900	3,41	118	472.23	337.95	72	24.44	109.84
21	--	--	--	--	--	--	--	--	--	--
22	2	3,060	2,900	4,319	149	593.07	384.32	65	29.84	178.91
23	1	2,440	2,280	1,966	86	367.80	177.61	48	13.10	178.59
24	1	1,700	1,620	2,220	138	291.20	175.47	60	16.61	99.10
25	4	7,660	7,380	9,390	127	1,393.23	747.33	54	59.55	586.35
26	--	--	--	--	--	--	--	--	--	--
27	--	--	--	--	--	--	--	--	--	--
28	1	2,000	1,730	2,000	116	301.24	233.53	80	18.40	49.11
29	--	--	--	--	--	--	--	--	--	--
30	3	3,770	3,140	3,790	121	805.65	337.29	42	25.37	442.99
31	4	4,450	4,060	4,694	123	1,021.36	418.54	41	32.33	570.49
32	3	5,040	3,800	4,531	119	734.09	405.57	55	30.74	297.78
33	--	--	--	--	--	--	--	--	--	--
34	--	--	--	--	--	--	--	--	--	--
35	4	4,940	4,400	5,491	125	813.27	499.98	61	38.18	275.11
36	4	3,320	2,660	3,229	121	616.73	341.30	47	23.32	304.95
37	3	2,580	2,090	2,765	132	480.03	245.17	51	17.88	217.03
38	1	2,600	2,360	2,800	119	361.68	252.36	70	18.07	90.75
39	4	5,840	5,610	5,699	102	1,036.98	508.68	49	37.99	490.31
40	--	--	--	--	--	--	--	--	--	--
41	1	3,060	2,660	3,573	134	695.26	318.39	46	24.00	352.87
42	--	--	--	--	--	--	--	--	--	--
43	2	6,840	6,060	7,379	122	989.14	651.91	66	48.01	285.62
54	--	--	--	--	--	--	--	--	--	--
55	1	3,400	3,040	3,562	117	599.46	315.12	53	22.32	262.02
Total	58	61,290	57,410	70,712	123	11,564.62	6,302.65	54	480.15	4,781.82

[1] As scaled by the Forest Service log scaling and grading bureau in log rafts, Scribner log rule.

[2] PLIB lumber tally volume as percentage of net scale volume.

[3] Lumber cubic volume as percentage of log cubic volume.

Table 5.—Summary of log scale, PLIB lumber tally, and cubic volumes by diameter classes—No. 1 logs

Log diameter (inches)	Number of logs	Log scale[1]		PLIB lumber tally		Cubic volume				
		Gross	Net	Volume	Recovery ratio[2]	Log	Lumber	Lumber recovery ratio[3]	Sawdust	Chippable residue
						Cubic feet				
24	1	800	800	1,044	130	141.00	92.56	66	6.57	41.87
25	3	3,780	3,670	4,498	123	698.56	399.82	57	29.17	269.57
26	3	4,290	3,700	4,364	118	803.13	393.42	49	31.14	378.57
27	7	9,520	8,850	10,536	119	1,628.04	938.02	58	66.83	623.19
28	7	10,760	10,050	10,840	108	2,019.03	967.79	48	77.73	973.51
29	6	8,430	7,800	9,050	116	1,621.17	812.34	50	60.61	748.22
30	5	12,570	11,300	13,084	116	2,186.19	1,175.39	54	88.53	922.27
31	5	7,820	6,790	8,111	119	1,514.21	722.02	48	54.98	737.21
32	1	1,560	1,420	859	60	507.81	76.35	15	5.93	425.53
33	4	6,670	5,450	8,029	147	1,218.02	711.84	58	51.17	455.01
34	2	3,300	2,860	3,909	137	505.01	346.68	69	25.09	133.24
35	1	1,750	1,600	1,876	117	344.40	167.98	50	12.83	153.65
36	--	--	--	--	--	--	--	--	--	--
37	1	1,670	1,300	2,022	156	223.35	180.25	81	14.16	28.94
38	2	4,920	4,300	4,877	113	661.78	434.36	66	33.03	194.39
39	3	3,690	3,410	3,471	102	895.34	307.50	34	21.93	565.91
40	3	4,810	3,940	3,525	89	732.97	314.96	43	24.84	393.17
41	3	6,670	6,060	7,420	122	1,248.85	658.01	53	47.72	543.12
42	3	6,880	5,960	8,214	138	1,083.75	729.51	67	54.72	299.52
43	--	--	--	--	--	--	--	--	--	--
44	1	2,590	2,350	3,470	148	560.51	307.28	55	22.61	230.62
45	1	2,860	2,350	3,390	144	398.41	301.40	76	22.20	74.81
46	1	2,580	2,130	2,645	121	331.14	235.09	71	18.30	77.75
47	1	3,520	3,040	3,633	119	493.09	324.82	66	27.24	141.03
48	1	2,600	1,940	2,901	150	334.10	256.94	77	18.00	59.16
49	2	6,290	5,250	7,081	135	1,325.09	633.59	48	46.18	645.32
50	1	2,600	2,600	2,500	96	520.42	222.17	43	15.80	282.45
51	--	--	--	--	--	--	--	--	--	--
52	1	3,800	3,510	4,090	117	677.89	363.60	54	27.55	286.74
53	3	7,430	3,710	2,423	65	1,207.08	216.52	18	17.86	972.70
54	--	--	--	--	--	--	--	--	--	--
55	1	3,970	3,290	4,088	124	523.26	364.01	70	28.03	131.22
56	1	3,820	3,160	3,415	108	720.26	306.65	43	23.54	390.07
Total	77	144,600	127,000	145,355	119	25,113.92	12,960.87	52	974.29	11,178.76

[1] As scaled by the Forest Service log scaling and grading bureau in log rafts, Scribner log rule.

[2] PLIB lumber tally volume as percentage of net scale volume.

[3] Lumber cubic volume as percentage of log cubic volume.

Table 6.—Summary of log scale, PLIB lumber tally, and cubic volumes by diameter classes—No. 2 logs

Log scaling diameter (inches)	Number of logs	Log scale[1/]		PLIB lumber tally		Cubic volume				
		Gross	Net	Volume	Recovery ratio[2/]	Log	Lumber	Lumber recovery ratio[3/]	Waste	Chippable residue
14	17	5,100	4,960	6,814	137	1,100.15	[illegible]	[illegible]	[illegible]	[illegible]
15	25	9,610	9,380	11,474	122	2,069.12	1,018.11	49	75.38	975.63
16	27	11,490	11,130	14,749	133	2,447.93	1,305.91	53	92.90	1,049.12
17	19	9,280	8,950	10,759	120	1,840.48	958.49	52	69.18	812.81
18	37	21,370	20,490	27,030	132	4,339.71	2,388.00	55	160.50	1,791.21
19	24	17,160	16,290	20,892	128	3,170.13	1,847.71	58	127.12	1,195.30
20	20	16,080	15,480	19,674	127	2,822.80	1,735.02	61	117.83	969.95
21	30	25,520	24,710	29,840	121	4,582.35	2,644.31	58	186.38	1,751.66
22	25	21,880	20,690	28,856	139	4,108.03	2,555.17	62	179.46	1,373.40
23	24	21,160	19,800	24,495	124	3,605.92	2,170.18	60	152.85	1,282.89
24	21	23,940	23,060	28,899	125	4,189.01	2,576.30	62	186.37	1,426.34
25	20	24,420	23,530	29,329	125	4,293.02	2,602.97	61	184.17	1,505.88
26	12	14,450	13,110	15,747	120	2,681.09	1,396.82	52	102.81	1,181.46
27	10	13,430	12,440	14,689	118	2,106.24	1,311.04	62	92.65	702.55
28	11	17,440	16,600	19,402	117	3,093.82	1,718.92	56	121.28	1,253.62
29	15	20,670	18,390	24,724	134	3,337.57	2,175.72	65	155.40	1,006.45
30	12	18,410	15,550	23,101	149	3,599.95	2,057.02	57	147.25	1,395.68
31	7	11,290	9,810	12,124	124	1,976.97	1,079.35	55	82.30	815.32
32	6	9,380	8,730	11,587	133	1,720.77	1,028.11	60	74.80	617.86
33	7	14,240	11,630	15,013	129	2,442.13	1,327.62	54	97.43	1,017.08
34	8	14,750	13,520	18,593	138	2,319.18	1,650.33	71	116.86	551.99
35	5	10,570	9,570	12,872	135	1,854.07	1,148.25	62	87.25	618.57
36	2	3,810	3,040	4,127	136	604.98	366.98	61	26.88	211.12
37	4	9,280	7,890	10,502	133	1,477.86	935.06	63	69.92	472.88
38	8	17,540	14,170	19,650	139	2,857.70	1,744.72	61	125.47	987.51
39	5	12,450	10,830	13,873	128	2,276.83	1,232.28	54	92.19	952.36
40	6	15,480	11,410	15,115	132	2,544.56	1,339.12	53	96.41	1,109.03
41	1	2,540	1,680	2,601	155	343.02	230.42	67	15.67	96.93
42	5	15,150	11,090	13,712	124	2,059.25	1,220.47	59	91.94	746.84
43	3	7,840	6,180	7,288	118	1,033.15	648.62	63	44.94	339.59
44	5	16,720	14,430	17,412	121	3,045.13	1,536.45	50	111.78	1,396.90
45	2	5,330	3,420	4,692	137	695.60	415.24	60	29.64	250.72
46	5	15,070	9,360	12,224	131	2,056.99	1,098.29	53	82.43	876.27
47	1	2,690	2,280	2,919	128	353.77	262.64	74	18.93	72.20
48	1	2,600	2,380	2,969	125	480.15	263.91	55	19.53	196.71
49	1	3,140	2,020	2,506	124	421.55	222.79	53	17.78	180.98
50	--	--	--	--	--	--	--	--	--	--
51	2	7,060	5,440	5,695	105	1,187.41	505.77	43	37.81	643.83
52	1	3,290	2,690	3,455	128	429.61	304.80	71	22.36	102.45
53	--	--	--	--	--	--	--	--	--	--
54	1	3,280	1,320	2,055	156	494.48	181.67	37	13.80	299.01
55	--	--	--	--	--	--	--	--	--	--
56	1	3,530	2,810	3,198	114	496.42	284.05	57	21.44	190.93
Total	436	498,440	440,260	564,656	128	86,558.90	50,093.53	58	3,592.24	32,873.13

[1/] As scaled by the Puget Sound Log Scaling and Grading Bureau in log rafts, Scribner log rule.

[2/] PLIB lumber tally volume as percentage of net scale volume.

[3/] Lumber cubic volume as percentage of log cubic volume.

Table 7.—Summary of log scale, PLIB lumber tally, and cubic volumes by diameter classes—No. 3 logs

Log scaling diameter (inches)	Number of logs	Log scale[1]		PLIB lumber tally		Cubic volume				
		Gross	Net	Volume	Recovery ratio[2]	Log	Lumber	Lumber recovery ratio[3]	Sawdust	Chippable residue
		Board feet		Percent	Cubic feet		Percent	Cubic feet		
6	12	870	870	1,518	174	246.53	136.33	55	10.96	99.24
7	28	1,960	1,930	2,850	148	578.21	256.83	44	22.30	299.08
8	35	3,300	3,170	4,909	155	1,015.84	437.82	43	36.16	541.86
9	40	4,180	3,950	6,081	154	1,186.06	543.82	46	44.63	597.61
10	34	5,600	5,330	7,383	139	1,327.84	656.82	49	51.34	619.68
11	39	6,390	6,200	8,200	132	1,557.81	730.15	47	56.95	770.71
12	54	12,440	12,000	17,600	147	2,980.51	1,561.48	52	113.83	1,305.20
13	52	14,290	13,580	19,209	141	3,310.89	1,708.89	52	125.11	1,476.89
14	24	6,390	5,950	9,379	158	1,470.05	833.2]	57	60.43	576.41
15	21	7,230	6,320	8,745	138	1,493.12	776.88	52	55.52	660.72
16	14	5,890	5,080	7,113	140	1,196.71	630.36	53	43.61	522.74
17	13	5,600	4,830	7,310	151	1,091.97	648.81	59	47.38	395.78
18	14	6,430	5,550	8,420	152	1,199.86	748.17	62	53.37	398.32
19	10	4,800	4,080	5,747	141	882.76	510.70	58	36.56	335.50
20	7	3,180	2,040	3,495	171	563.88	311.53	55	23.65	228.70
21	8	6,640	5,750	8,243	143	1,145.02	729.43	64	51.35	364.24
22	7	6,050	4,980	6,790	136	1,029.18	602.64	59	43.14	383.40
23	8	8,500	6,670	9,517	143	1,363.26	847.69	62	62.55	453.02
24	5	6,020	4,980	6,506	131	957.92	579.70	61	41.86	336.36
25	11	10,210	7,810	11,866	152	1,628.66	1,053.97	65	75.25	499.44
26	6	5,570	4,250	5,750	135	852.39	509.99	60	37.85	304.55
27	4	3,980	2,410	4,605	191	625.49	409.83	66	28.69	186.97
28	5	5,830	4,390	8,677	198	893.98	767.74	86	53.09	73.15
29	1	2,010	1,790	1,777	99	300.50	164.42	55	12.40	123.68
30	2	2,950	2,380	3,301	139	495.64	293.48	59	21.22	180.94
31	3	6,160	5,280	6,314	120	998.64	564.10	56	39.28	395.26
32	1	2,430	1,840	1,916	104	347.62	170.68	49	12.25	164.69
33	2	3,230	1,560	1,877	120	440.68	166.28	38	12.20	262.20
34	2	3,200	2,900	4,375	151	504.06	387.69	77	28.19	88.18
35	--	--	--	--	--	--	--	--	--	--
36	1	1,500	580	1,178	203	224.43	104.37	47	7.33	112.73
37	2	4,120	2,490	5,180	208	596.62	452.76	76	33.49	110.37
38	1	2,140	1,930	2,465	128	324.17	219.36	68	16.18	88.63
39	1	2,240	1,230	2,693	219	366.63	243.11	66	17.70	105.82
40	1	1,660	830	1,442	174	227.54	128.50	56	10.49	88.55
41	--	--	--	--	--	--	--	--	--	--
42	--	--	--	--	--	--	--	--	--	--
43	--	--	--	--	--	--	--	--	--	--
44	1	2,410	930	1,747	188	302.72	155.02	51	11.70	136.00
45	--	--	--	--	--	--	--	--	--	--
46	--	--	--	--	--	--	--	--	--	--
47	--	--	--	--	--	--	--	--	--	--
48	1	2,810	2,180	2,484	114	578.50	224.72	39	16.63	337.15
49	2	6,070	5,060	7,339	145	872.42	651.19	75	46.00	175.23
50	-	--	--	--	--	--	--	--	--	--
51	-	--	--	--	--	--	--	--	--	--
52	-	--	--	--	--	--	--	--	--	--
53	-	--	--	--	--	--	--	--	--	--
54	1	3,280	1,380	700	51	425.69	63.80	15	5.41	356.48
Total	473	187,560	154,480	224,701	145	35,603.80	19,982.27	56	1,466.05	14,155.48

[1] As scaled by the Puget Sound Log Scaling and Grading Bureau in log rafts, Scribner log rule.

[2] PLIB lumber tally volume as percentage of net scale volume

[3] Lumber cubic volume as percentage of log cubic volume.

Table 8.—Summary of log scale, PLIB lumber tally, and cubic volumes by diameter classes—all logs

Log scaling diameter (inches)	Number of logs	Log scale[1]		PLIB lumber tally		Cubic volume				
		Gross	Net	Volume	Recovery ratio[2]	Log	Lumber	Lumber recovery ratio[3]	Sawdust	Chippable residue
		Board feet								
6	12	870	870	1,518	174	246.53	136.33	55	10.96	99.24
7	28	1,960	1,930	2,850	148	578.21	256.83	44	22.30	299.08
8	35	3,300	3,170	4,909	155	1,015.84	437.82	43	36.16	541.86
9	40	4,180	3,950	6,081	154	1,186.06	543.82	46	44.63	597.61
10	34	5,600	5,330	7,383	139	1,327.84	656.82	49	51.34	619.68
11	39	6,390	6,200	8,200	132	1,557.81	730.15	47	56.95	770.71
12	54	12,440	12,000	17,600	147	2,980.51	1,561.48	52	113.83	1,305.20
13	52	14,290	13,580	19,209	141	3,310.89	1,708.89	52	125.11	1,476.89
14	41	11,490	10,910	16,193	148	2,570.20	1,438.11	56	103.58	1,028.51
15	46	16,840	15,700	20,219	129	3,562.24	1,794.99	50	130.90	1,636.35
16	41	17,380	16,210	21,862	135	3,644.64	1,936.27	53	136.51	1,571.86
17	32	14,880	13,780	18,069	131	2,932.45	1,607.30	55	116.56	1,208.59
18	51	27,800	26,040	35,450	136	5,539.57	3,136.17	57	213.87	2,189.53
19	34	21,960	20,370	26,639	131	4,052.89	2,358.41	58	163.68	1,530.80
20	27	19,260	17,520	23,169	132	3,386.68	2,046.55	60	141.48	1,198.65
21	38	32,160	30,460	38,083	125	5,727.37	3,373.74	59	237.73	2,115.90
22	32	27,930	25,670	35,646	139	5,137.21	3,157.81	61	222.60	1,756.80
23	32	29,660	26,470	34,012	128	4,969.18	3,017.87	61	215.40	1,735.91
24	27	30,820	28,840	36,449	126	5,287.93	3,248.56	61	234.80	1,804.57
25	34	38,360	35,010	45,693	131	6,620.24	4,056.76	61	288.59	2,274.89
26	21	24,310	21,060	25,861	123	4,336.61	2,300.23	53	171.80	1,864.58
27	21	26,930	23,700	29,820	126	4,359.77	2,658.89	61	188.17	1,512.71
28	23	34,030	31,040	38,919	125	6,006.83	3,454.45	58	252.10	2,300.28
29	22	31,110	27,980	35,551	127	5,259.24	3,152.48	60	228.41	1,878.35
30	24	36,970	32,090	43,298	135	6,754.01	3,863.84	57	281.44	2,608.73
31	15	25,270	21,880	26,549	121	4,489.82	2,365.47	53	176.56	1,947.79
32	10	16,590	14,890	18,681	125	3,169.27	1,659.46	52	122.82	1,386.99
33	14	26,630	20,920	26,885	129	4,468.13	2,381.35	53	173.90	1,912.88
34	13	22,950	20,680	28,816	139	3,619.45	2,560.19	71	186.75	872.51
35	10	19,980	17,760	23,115	130	3,581.76	2,063.56	58	159.63	1,358.57
36	3	5,310	3,620	5,305	147	829.41	471.35	57	34.21	323.85
37	7	15,070	11,680	17,704	152	2,297.83	1,568.07	68	117.57	612.19
38	12	26,600	21,730	29,614	136	4,134.59	2,631.87	64	193.08	1,309.64
39	7	18,380	15,670	20,037	128	3,538.80	1,782.89	50	131.82	1,624.09
40	11	25,720	19,320	23,872	124	4,310.72	2,119.87	49	157.11	2,033.74
41	5	13,660	11,550	14,715	127	2,613.23	1,306.97	50	95.72	1,210.54
42	10	27,070	20,850	26,457	127	3,877.09	2,355.55	61	177.40	1,344.14
43	3	7,840	6,180	7,288	118	1,033.15	648.62	63	44.94	339.59
44	7	21,720	17,710	22,629	128	3,908.36	1,998.75	51	146.09	1,763.52
45	5	13,130	10,170	13,703	135	1,907.28	1,216.62	64	90.02	600.64
46	7	20,620	14,200	18,098	127	3,007.86	1,624.84	54	124.05	1,258.97
47	3	8,690	7,030	9,317	133	1,326.89	832.58	63	64.05	430.26
48	4	10,610	8,880	11,198	126	1,754.43	998.43	57	72.23	683.77
49	7	21,340	17,940	22,625	126	3,656.04	2,016.25	55	147.95	1,491.84
50	1	3,040	2,600	2,500	96	520.42	222.17	43	15.80	282.45
51	3	10,710	8,100	9,268	114	1,882.67	824.16	44	61.81	996.70
52	2	7,090	6,200	7,545	122	1,107.50	668.40	60	49.91	389.19
53	4	14,470	9,770	9,802	100	2,196.22	872.03	40	65.87	1,258.32
54	2	6,560	2,700	2,755	102	920.17	245.47	27	19.21	655.49
55	2	7,370	6,330	7,650	121	1,122.72	679.13	60	50.35	393.24
56	2	7,350	5,970	6,613	111	1,216.68	590.70	49	44.98	581.00
Total	1,009	894,690	774,210	1,005,424	130	158,841.24	89,339.32	56	6,512.73	62,989.19

[1] As scaled by the Puget Sound Log Scaling and Grading Bureau in log rafts, Scribner log rule.

[2] PLIB lumber tally volume as percentage of net scale volume.

[3] Lumber cubic volume as percentage of log cubic volume.

Table 9.—PLIB lumber grade yields for Select logs by log scaling diameter

Log scaling diameter (inches)	Number of logs	Total lumber tally	No. 2 Clear	No. 3 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 3 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	Construction	Standard	Utility	Economy
		Board feet							Percent							
30	2	3,812	35.31	4.67	10.62	--	4.80	--	21.62	23.24	--	--	--	0.24	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
32	2	4,319	42.65	3.70	4.98	--	--	5.83	23.76	13.45	4.91	--	0.23	.12	0.37	--
33	1	1,866	12.61	--	1.71	5.89	14.65	27.06	13.43	4.27	7.93	--	--	--	1.02	1.02
34	1	1,939	38.47	13.00	23.16	1.86	--	2.89	7.94	12.69	--	--	--	--	--	--
35	4	8,367	46.79	1.88	6.44	--	1.20	4.47	12.73	16.58	9.56	--	.10	.11	.10	.06
36	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
37	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
38	1	2,622	52.59	--	--	--	--	1.83	13.81	26.05	--	--	1.22	--	--	--
39	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
40	1	3,790	28.18	4.12	3.59	1.78	4.43	6.33	9.55	20.05	16.25	--	--	--	.71	--
41	2	4,694	46.02	1.92	4.33	--	1.56	3.45	20.52	9.03	9.01	--	.21	.26	.17	--
42	2	4,531	37.21	2.65	2.89	--	--	6.55	20.46	22.45	7.48	--	.31	--	--	--
43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
44	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
45	1	5,621	46.59	1.00	6.01	8.75	3.77	2.90	15.41	7.95	7.38	--	--	--	.23	--
46	1	3,229	53.61	.93	5.57	--	--	7.99	10.22	14.18	5.20	--	.99	.43	--	--
47	1	2,765	42.03	2.60	--	--	--	--	29.95	15.84	9.11	--	.47	--	--	--
48	1	2,844	7.45	8.83	30.94	6.54	2.75	--	17.30	26.16	--	--	.25	.28	--	--
49	2	5,699	53.68	1.02	1.58	--	.42	2.74	19.32	11.32	9.09	--	.42	.21	--	.21
50	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
51	1	3,573	43.46	--	10.08	1.34	5.32	2.55	4.03	25.36	7.72	--	.34	1.18	.22	--
52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
53	2	7,379	33.50	4.47	6.78	4.15	--	1.30	32.76	10.31	5.37	--	.45	.15	.77	--
54	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
55	1	3,562	48.34	--	3.37	.67	1.45	5.39	21.22	13.76	6.06	--	.28	.45	--	--
Total	28	70,712	40.90	2.70	7.14	1.41	1.52	4.13	18.18	15.50	6.77	--	.29	.20	.22	.05

Table 10.—PLIB lumber grade yields for No. 1 logs by log scaling diameter

Log scaling diameter (inches)	Number of logs	Total lumber tally	No. 2 Clear	No. 3 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 3 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	Construction	Standard	Utility	Economy
		Board feet							Percent							
24	1	1,044	--	--	18.39	5.17	7.66	4.60	26.82	8.05	29.31	--	--	--	--	--
25	3	4,498	8.94	--	25.46	17.01	4.00	8.14	12.25	19.54	4.27	--	0.40	--	--	--
26	3	4,364	11.27	--	14.30	8.20	--	5.09	21.91	24.06	12.74	1.24	.32	0.18	0.69	--
27	7	10,526	5.20	4.37	28.43	8.53	6.29	2.03	9.58	20.88	13.03	.76	.55	.23	.11	--
28	7	10,840	21.84	4.21	23.32	5.18	7.29	3.38	8.75	20.71	4.08	--	.66	.42	.18	--
29	6	9,050	19.93	4.54	24.00	2.24	3.66	2.39	12.45	19.64	10.76	--	.11	.22	.06	--
30	8	13,064	14.19	5.63	20.31	7.84	11.59	3.41	18.04	11.83	6.64	--	.40	--	.08	0.06
31	5	8,111	8.67	2.10	18.48	10.70	6.52	15.40	14.97	16.79	4.59	.49	1.11	.18	--	--
32	1	859	18.39	--	--	--	--	17.23	4.19	40.40	19.79	--	--	--	--	--
33	4	8,029	11.38	4.78	21.90	9.71	10.46	11.08	12.65	15.89	1.74	--	.07	.24	.07	--
34	3	3,909	26.86	1.38	14.27	6.57	1.23	9.00	11.56	15.35	13.20	--	--	.56	--	--
35	1	1,876	38.91	6.40	--	2.77	--	4.05	4.48	28.14	6.40	8.00	.85	--	--	--
36	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
37	1	2,022	48.52	--	--	--	.94	--	19.29	13.40	16.12	--	1.14	.30	.30	--
38	2	4,877	21.71	3.28	15.21	1.83	1.09	11.40	9.70	16.24	15.77	2.58	.18	--	--	--
39	1	3,471	25.76	5.76	22.53	--	2.07	8.93	13.37	20.20	1.38	--	--	--	--	--
40	2	3,525	33.73	--	--	2.04	--	13.19	12.94	30.52	7.38	--	.20	--	--	--
41	2	7,420	39.47	1.94	3.23	4.12	2.26	7.71	19.12	17.61	4.04	--	.22	.26	--	--
42	3	8,214	42.20	1.07	2.26	.68	1.22	3.46	17.10	23.90	6.38	--	1.05	.68	--	--
43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
44	1	3,470	17.58	4.78	3.17	8.99	4.84	3.31	21.35	32.80	1.21	--	1.15	.32	.49	--
45	1	3,390	46.76	12.30	1.77	--	.80	6.67	12.01	16.08	2.48	--	.18	.97	--	--
46	1	2,645	39.32	--	16.71	2.27	3.93	--	10.06	23.71	2.12	--	1.44	.45	--	--
47	1	3,633	41.95	7.18	3.74	2.20	--	1.16	9.25	26.92	4.10	1.54	.52	.69	.74	--
48	1	2,901	23.78	12.82	15.72	11.58	--	8.27	10.86	3.72	13.24	--	--	--	--	--
49	2	7,081	36.69	.85	.79	.59	--	7.40	30.43	17.02	4.63	.23	.71	--	.66	--
50	1	2,500	24.80	--	6.72	--	2.80	17.36	22.44	16.20	7.20	--	2.00	.48	--	--
51	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
52	1	4,090	37.70	6.06	2.44	--	1.32	7.97	51.67	22.25	5.72	--	.22	--	.64	--
53	2	2,423	27.20	.41	--	--	--	5.45	29.34	26.87	9.86	--	.54	--	.33	--
54	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
55	1	4,088	39.36	5.41	5.48	--	--	--	23.85	10.47	13.45	1.37	.32	.20	.37	--
56	1	3,415	36.72	--	6.15	--	1.41	3.16	32.65	10.92	6.50	--	.56	.82	1.11	--
Total	72	145,355	4.27	3.53	13.79	4.97	4.03	6.14	15.73	18.83	7.38	.40	.50	.25	.18	.01

Table 11.—PLIB lumber grade yields for No. 2 logs by log scaling diameter

Log scaling diameter (inches)	Number of logs	Total lumber tally	No. 2 Clear	No. 3 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 3 Common	Factory Select	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Economy
		[illegible]	- - -				- -								
14	17	6,814	0.07	--	26.89	[illegible]	27.71	7.69	—	8.83	3.23	--	0.47	0.13	[illegible]	--
15	25	11,474	1.39	--	35.74	26.47	23.83	3.28	[illegible]	[illegible]	[illegible]	—	.51	.07	0.10	0.11
16	27	14,749	.47	—	29.94	21.41	21.89	8.33	[illegible]	13.26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	19	10,759	.30	--	35.46	18.48	16.30	10.67	[illegible]	9.41	3.90	[illegible]	.72	[illegible]	[illegible]	—
18	37	27,030	.57	0.06	31.43	23.60	7.75	13.27	[illegible]	[illegible]	6.47	[illegible]	.29	.03	.04	[illegible]
19	24	20,892	.81	--	31.25	26.22	20.96	9.60	.40	6.50	4.00	--	[illegible]	[illegible]	.11	[illegible]
20	20	19,674	.41	--	33.63	19.06	19.37	12.08	1.39	[illegible]	[illegible]	—	.24	.15	.06	-
21	30	29,840	1.94	.91	26.35	24.83	17.62	6.49	4.13	12.18	4.92	[illegible]	.29	.10	[illegible]	-
22	25	28,856	1.98	.97	33.25	12.69	13.41	8.49	6.24	15.77	6.98	--	[illegible]	[illegible]	[illegible]	.12
23	24	24,495	2.47	.89	29.21	16.28	16.89	8.71	5.22	13.74	6.32	[illegible]	.04	.13	[illegible]	—
24	21	28,899	5.88	.98	32.10	13.57	13.40	9.13	5.09	12.56	6.21	[illegible]	.78	.09	.13	-
25	20	29,329	4.53	.90	29.95	17.57	10.64	8.25	8.47	15.24	3.58	.47	[illegible]	[illegible]	[illegible]	—
26	12	15,747	10.06	1.88	18.87	5.63	8.85	9.81	8.88	24.39	11.33	[illegible]	.16	[illegible]	.13	--
27	10	14,689	6.50	--	23.41	11.89	18.23	5.79	7.26	21.72	5.19	-	—	—	--	-
28	11	19,402	5.31	.62	23.28	11.36	11.72	14.49	7.28	19.02	6.80	—	--	[illegible]	.12	—
29	15	24,724	12.00	2.10	22.74	7.94	6.65	10.06	7.47	20.62	10.11	--	.17	.11	.02	[illegible]
30	12	23,101	13.97	1.63	27.23	9.44	8.91	5.51	6.38	23.35	3.19	—	[illegible]	.05	[illegible]	--
31	7	12,124	9.59	6.29	14.85	8.44	10.40	14.82	4.96	17.16	12.91	.15	[illegible]	.08	[illegible]	-
32	6	11,587	10.87	.52	16.98	9.74	10.53	12.28	10.77	18.89	9.03	[illegible]	.23	.15	-	-
33	7	15,013	6.57	.33	8.37	5.36	8.84	14.69	15.18	27.10	12.07	.67	.31	[illegible]	.31	.17
34	8	18,593	13.21	1.50	13.05	8.51	7.83	13.07	15.97	20.01	5.89	.32	[illegible]	.06	[illegible]	.09
35	5	12,872	24.67	1.32	12.65	1.63	4.50	5.62	16.43	22.90	9.60	[illegible]	.52	—	.16	--
36	2	3,127	11.32	2.91	1.94	8.53	15.73	21.13	13.25	11.10	12.75	1.36	—	—	--	--
37	4	10,502	17.83	3.92	6.63	5.98	4.27	10.53	20.27	17.56	11.32	--	1.16	.21	.31	--
38	8	19,650	14.99	1.23	9.05	4.98	8.17	7.69	22,71	19.54	10.76	[illegible]	.35	[illegible]	[illegible]	.07
39	5	13,873	26.68	1.56	8.03	6.29	4.18	7.78	16.70	17.26	10.62	--	.19	[illegible]	.72	--
40	6	15,115	23.98	1.98	2.44	3.64	7.87	[illegible]	12.40	22.98	7.30	--	.21	.03	[illegible]	.17
41	1	2,601	3.11	--	3.69	--	6.77	10.53	21.84	44.14	9.92	[illegible]	--	[illegible]	[illegible]	--
42	5	13,712	13.69	3.65	4.77	2.95	5.27	15.64	16.28	[illegible]	13.68	.59	.11	.31	[illegible]	.19
43	3	7,288	3.66	4.12	9.82	12.57	8.34	8.93	15.82	25.26	10.04	[illegible]	[illegible]	[illegible]	[illegible]	—
44	5	17,412	21.13	1.52	16.40	3.86	6.63	16.57	18.75	10.64	3.88	--	.45	.16	[illegible]	--
45	2	4,692	23.85	2.49	8.35	.90	5.46	2.37	23.74	18.95	13.30	[illegible]	[illegible]	[illegible]	.60	[illegible]
46	5	12,224	17.82	3.86	10.37	1.35	.69	7.89	23.16	18.51	15.03	[illegible]	.62	[illegible]	.40	--
47	1	2,919	9.22	--	8.02	8.91	5.93	16.31	12.23	31.62	7.19	—	.17	[illegible]	[illegible]	[illegible]
48	1	2,969	51.26	2.02	--	4.04	5.25	--	21.72	11.75	[illegible]	[illegible]	1.25	.27	2.43	—
49	1	2,506	6.42	--	.28	--	-	36.31	6.86	[illegible]	28.49	[illegible]	-	1.40	--	--
50	--	--	--	--	--	--	--	-	[illegible]	--	-	[illegible]	--	--	[illegible]	[illegible]
51	2	5,695	13.59	.56	10.71	1.83	4.07	11.34	18.96	24.00	10.68	2.46	[illegible]	[illegible]	[illegible]	--
52	1	3,455	20.26	3.01	16.79	--	2.52	—	20.38	[illegible]	11.17	--	[illegible]	.72	.52	--
53	--	--	--	--	-	--	--	[illegible]	[illegible]	--	--	-	--	--	--	--
54	1	2,055	23.45	--	4.28	--	11.29	18.39	18.78	13.82	9.98	--	--	--	[illegible]	[illegible]
55	--	--	--	--	--	--	--	[illegible]	-	[illegible]	--	--	--	--	--	--
56	1	3,198	4.38	2.72	8.63	1.88	3.75	5.00	23.23	24.45	22.64	3.00	[illegible]	--	--	--
Total	456	564,656	8.87	1.27	21.64	12.30	11.42	10.11	9.35	16.85	7.40	.15	.32	.13	[illegible]	.03

Table 12.—PLIB lumber grade yields for No. 3 logs by log scaling diameter

Log scaling diameter (inches)	Number of logs	Total lumber tally	No. 2 Clear	No. 3 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 3 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	Construction	Standard	Utility	Economy
		Board feet						Percent of total lumber tally								
6	12	1,518	--	--	5.47	34.25	29.45	26.61	--	4.22	--	--	--	--	--	--
7	28	2,850	3.09	--	24.49	32.28	32.60	3.37	--	--	1.40	--	2.77	--	--	--
8	35	4,909			30.86	26.40	33.06	8.03	--	--	--	1.22	.43	--	--	--
9	40	6,081	--	--	15.36	31.25	28.20	16.74	--	2.63	2.10	--	2.76	0.62	0.34	--
10	34	7,383	.04	--	17.24	32.29	36.45	11.82	--	.65	--	--	.68	.83	--	--
11	19	8,200	—	--	34.36	28.74	23.77	10.30	--	.73	1.27	--	.29	--	.43	--
12	54	17,600	--	--	19.86	30.06	33.19	10.43	1.07	4.41	.74	--	.20	--	.05	--
13	52	19,209	.50	0.14	22.18	25.73	32.15	10.70	.26	2.03	5.27	--	.49	.43	.03	0.09
14	24	9,379	--	--	18.91	28.13	29.17	19.94	--	1.96	1.58	--	.07	.17	.06	--
15	21	8,745	--	--	7.98	32.88	38.66	11.64	--	3.42	3.89	--	.51	.35	.62	.05
16	14	7,113	--	—	11.89	26.53	27.57	24.98	--	5.03	3.63	--	.22	.10	.04	--
17	13	7,310	—	-	4.57	19.59	24.54	47.52	--	2.79	.33	--	.07	.10	.31	.18
18	14	8,420	—	--	6.29	31.14	27.66	30.00	--	4.42	--	--	--	--	.50	--
19	10	5,747	--	--	8.14	19.63	28.52	36.56	.85	2.68	2.82	--	.35	.30	.16	--
20	7	3,495	--	—	1.80	19.51	33.79	35.48	--	---	8.18	--	.40	--	.83	--
21	8	8,243	.39	--	8.98	27.94	24.01	12.86	--	15.21	9.01	1.09	.30	.21	--	--
22	7	6,790	3.53	—	13.18	10.03	15.98	31.87	2.12	12.12	10.18	--	.12	.41	.10	.35
23	8	9,517	2.19	—	9.07	11.15	20.83	40.41	1.89	4.98	7.50	--	.29	.70	.94	.05
24	5	6,506	1.11	--	13.59	17.54	19.72	23.99	—	16.97	6.03	--	.74	.08	.25	—
25	11	11,866	.22	--	8.30	20.71	18.77	31.08	4.97	5.12	8.73	.84	.76	.21	.19	.09
26	6	5,750	2.80	--	11.03	19.10	14.40	33.74	3.83	9.79	4.14	--	.75	.14	.30	--
27	4	4,605	--	--	1.30	8.25	19.87	23.37	3.65	18.98	24.58	--	--	--	--	--
28	5	8,677	--	.03	8.63	10.14	19.55	14.86	13.26	21.41	11.86	--	—	--	--	.25
29	1	1,777	1.74	--	8.10	9.45	4.73	25.32	3.55	27.46	17.56	--	1.07	1.01	--	—
30	2	3,301	2.48	--	4.24	3.76	15.15	22.72	4.12	24.45	23.08	--	--	--	--	--
31	3	6,314	3.39	.57	2.49	5.31	16.85	45.09	2.26	16.72	6.94	--	.38	—	--	--
32	1	1,916	5.22	6.26	1.25	--	-	--	10.13	30.27	32.15	13.26	--	--	1.46	--
33	2	1,877	--	--	16.20	9.54	15.24	33.30	1.92	21.58	2.24	--	--	--	--	--
34	2	4,375	1.60	2.47	6.99	12.07	11.43	6.93	20.94	23.45	12.89	--	.25	.82	.16	--
35	--	--	--	--	--	-	--	--	--	--	--	--	--	--	--	--
36	1	1,178	--	--	32.00	2.04	19.52	46.43	--	--	--	--	--	--	--	--
37	2	5,180	2.43	1.08	3.71	9.88	23.86	19.03	5.60	20.46	13.94	--	--	--	--	--
38	1	2,465	2.43	2.27	--	4.38	6.77	11.76	7.63	24.67	37.89	2.19	--	--	--	--
39	1	2,693	8.91	--	4.68	1.49	8.69	10.25	16.34	21.61	28.04	--	--	--	--	--
40	1	1,442	18.24	6.87	1.87	--	--	15.95	10.68	11.37	34.12	--	--	--	.90	--
41	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
42	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
43	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
44	1	1,747	--	--	--	33.89	11.28	32.05	8.19	14.60	--	--	--	--	--	--
45	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
46	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
47	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
48	1	2,484	46.78	5.80	--	--	--	9.62	12.20	13.53	11.63	--	.44	--	--	--
49	2	7,339	10.71	--	8.01	3.60	12.81	7.98	16.79	25.58	13.65	.65	--	.22	--	--
50	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
51	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
52	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
53	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
54	1	700	--	--	--	11.14	--	11.14	--	6.00	68.86	--	--	--	--	2.86
Total	473	224,701	1.82	.29	12.54	20.26	23.77	20.99	3.13	8.92	7.18	.27	.39	.20	.19	.05

Table 13.—PLIB lumber grade yields for all logs by log scaling diameter

Log scaling diameter (inches)	Number of logs	Total lumber tally	No. 2 Clear	No. 3 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 3 Common	Factory Select	No. Shop	[illegible]	Shop	[illegible]	Standard	Utility	[illegible]
		Board feet									*ld*					
6	12	1,518	—	--	5.47	34.26	29.45	26.61	—	4.22	—	-	--	-	--	—
7	28	2,850	3.09	--	24.49	32.28	32.60	3.37	—	--	[illegible]	--	--	—	—	—
8	35	4,909	--	--	30.86	26.40	33.06	8.03	—	--	—	1.22	.43	—	-	—
9	40	6,081	--	—	15.36	31.24	28.19	16.74	—	2.63	2.10	—	-	0.62	—	—
10	34	7,383	.05	--	17.24	32.29	36.45	11.82	—	.65	—	—	.68	.83	—	--
11	39	8,200	--	—	34.46	28.74	23.77	10.30	—	.73	1.27	-	.20	—	-	-
12	54	17,600	--	--	19.86	[illegible]	33.19	[illegible]	1.07	4.41	.74	—	.20	-	-	—
13	52	19,209	.47	0.14	22.19	25.74	32.16	10.70	.26	[illegible]	—	--	.49	.43	.03	0.09
14	41	16,193	.03	--	22.27	26.80	28.56	14.78	—	4.85	[illegible]	-	.24	.15	.04	-
15	46	20,219	.79	--	23.74	29.24	30.24	6.89	.65	3.42	[illegible]	—	.51	[illegible]	[illegible]	.08
16	41	21,862	.32	[illegible]	24.07	23.08	23.74	13.75	—	10.58	[illegible]	—	[illegible]	.03	[illegible]	[illegible]
17	32	18,069	.18	--	22.96	18.93	19.64	25.58	2.37	6.73	2.46	-	.45	.23	.41	.07
18	51	35,450	.43	.05	25.46	25.39	12.48	17.25	1.71	11.00	4.94	—	[illegible]	.02	[illegible]	--
19	34	26,639	.04	--	26.26	24.79	22.59	15.42	.50	5.67	[illegible]	—	[illegible]	.08	[illegible]	—
20	27	23,169	.35	--	28.83	19.13	21.54	15.61	[illegible]	8.86	3.94	--	.26	.13	[illegible]	—
21	38	48,083	1.61	.71	22.59	25.50	19.00	7.87	[illegible]	12.84	5.81	.43	[illegible]	.12	[illegible]	--
22	42	35,646	2.28	.79	20.43	12.19	13.90	12.95	[illegible]	15.07	7.34	--	.21	.18	.04	.17
23	32	34,012	2.39	.64	23.57	14.84	17.99	17.58	4.29	11.29	[illegible]	-	11	[illegible]	[illegible]	.01
24	27	36,449	4.86	.77	28.41	14.04	14.37	11.65	4.80	13.22	6.84	.05	.75	.09	[illegible]	—
25	34	45,693	3.85	.58	23.89	18.33	12.10	14.17	7.94	13.03	4.99	[illegible]	.45	.10	.05	.02
26	21	25,861	8.65	1.14	16.35	9.06	8.59	14.43	9.95	21.09	[illegible]	[illegible]	[illegible]	[illegible]	.26	—
27	21	29,820	5.06	1.54	21.77	10.14	14.27	7.18	7.52	21.00	10.96	.27	.19	.08	.04	—
28	24	38,919	8.73	1.49	20.03	9.37	12.23	11.48	[illegible]	20.02	7.17	--	[illegible]	.12	.11	[illegible]
29	22	35,551	13.51	2.62	22.33	6.56	5.79	8.87	8.55	20.71	10.65	—	.20	[illegible]	.03	.01
30	24	43,298	15.04	2.98	21.92	7.69	[illegible]	5.70	11.07	19.94	5.47	—	.26	.05	[illegible]	.02
31	15	26,549	7.83	3.65	13.02	8.38	10.75	22.20	7.38	16.95	8.95	.22	[illegible]	.09	.05	-
32	10	18,681	17.99	1.82	11.81	[illegible]	6.53	[illegible]	13.40	19.79	10.94	[illegible]	.20	.12	.24	—
33	14	26,885	7.99	1.61	13.23	6.98	10.20	15.82	13.37	21.70	8.00	.37	.19	.10	.27	[illegible]
34	13	28,816	15.00	2.40	12.98	8.34	6.95	[illegible]	15.59	19.41	[illegible]	.21	.26	.24	[illegible]	[illegible]
35	10	23,115	33.84	1.93	9.37	1.13	2.94	5.07	14.12	21.04	9.33	.65	[illegible]	[illegible]	12	[illegible]
36	3	5,305	8.80	2.26	8.61	7.09	16.57	[illegible]	10.31	8.63	9.92	[illegible]	—	-	--	-
37	7	17,704	16.83	2.64	5.02	6.44	9.62	11.82	15.87	17.93	12.64	--	.82	.16	.22	—
38	12	29,614	18.38	1.54	9.00	4.14	6.17	8.12	18.44	20.00	12.89	.61	[illegible]	.21	.10	[illegible]
39	7	20,037	23.86	2.08	10.09	4.55	4.42	8.31	16.08	18.35	[illegible]	—	.13	.27	[illegible]	—
40	11	23,872	25.74	2.32	2.23	3.68	[illegible]	14.45	11.92	22.93	10.35	—	[illegible]	[illegible]	[illegible]	[illegible]
41	5	14,715	35.13	1.39	4.47	2.08	3.15	[illegible]	20.05	[illegible]	6.67	—	.18	.21	[illegible]	--
42	10	26,457	26.57	2.68	3.67	1.74	3.11	10.30	17.25	22.80	10.35	[illegible]	.43	[illegible]	[illegible]	.10
43	3	7,288	3.66	4.12	9.82	12.57	8.34	8.93	15.82	25.26	10.04	—	[illegible]	[illegible]	.07	--
44	7	22,629	18.96	1.90	13.11	6.96	[illegible]	15.74	[illegible]	14.34	[illegible]	—	[illegible]	.17	.08	-
45	5	13,703	38.85	4.31	5.77	3.90	[illegible]	3.65	17.42	[illegible]	8.20	--	.04	.24	.30	--
46	7	18,098	27.35	2.77	10.44	1.40	[illegible]	[illegible]	18.94	18.50	11.39	—	.81	.34	[illegible]	-
47	3	9,317	31.72	[illegible]	3.97	3.65	1.86	5.56	16.32	25.10	6.56	[illegible]	.40	[illegible]	.29	-
48	4	11,198	32.02	7.39	11.93	5.73	1.96	4.28	15.67	[illegible]	6.01	—	[illegible]	[illegible]	.64	--
49	7	22,625	29.19	.52	[illegible]	1.35	4.26	9.62	20.60	18.37	[illegible]	[illegible]	[illegible]	.28	.21	.05
50	1	2,500	24.80	--	6.72	--	2.80	17.36	22.44	16.20	7.20	—	2.00	.48	[illegible]	[illegible]
51	3	9,268	25.11	.35	10.47	1.64	3.94	7.95	13.21	24.53	[illegible]	1.51	[illegible]	[illegible]	[illegible]	[illegible]
52	2	7,545	29.72	4.67	9.01	--	[illegible]	4.32	17.83	23.26	8.22	-	[illegible]	.33	-	--
53	4	9,802	31.94	3.47	5.10	3.12	--	2.33	31.91	14.41	6.48	--	[illegible]	.11	[illegible]	-
54	2	2,755	17.50	--	3.19	[illegible]	8.42	16.55	14.01	11.83	24.94	--	—	-	-	.73
55	2	7,650	43.54	2.75	4.50	.31	0.21	2.51	22.63	12.00	10.01	[illegible]	[illegible]	.31	.20	—
56	2	6,613	21.08	[illegible]	[illegible]	.91	2.54	4.05	28.10	17.47	14.31	[illegible]	.44	.42	—	--
Total	1,009	1,005,424	11.77	1.48	17.43	12.34	12.48	11.52	9.50	15.25	[illegible]	.20	[illegible]	[illegible]	[illegible]	[illegible]

Table 14.—The distribution of study lumber by PLIB grade, thickness, and width for Select logs

Thickness	Width	No. 2 Clear	No. 3 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 3 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	Construction	Standard	Utility	Economy	Lumber volume Percent	Lumber volume Board feet
1	4	--	--	--	--	--	--	--	--	--	--	--	--	100.0	--	1/	3
	5	82.9	--	--	--	--	--	--	--	--	--	--	5.7	5.7	5.7	0.1	88
	6	81.0	2.0	--	--	--	--	--	--	--	--	10.9	1.7	4.4	--	.4	294
	8	62.3	20.7	17.0	--	--	--	--	--	--	--	--	--	--	--	.1	53
2	4	69.0	11.1	2.6	--	--	--	--	--	--	--	5.2	7.8	4.3	--	.6	461
	6	80.7	--	.8	--	--	--	1.2	--	--	--	9.4	5.6	1.3	1.0	1.7	1,190
	7	100.0	--	--	--	--	--	--	--	--	--	--	--	--	--	1/	14
	8	58.9	--	4.8	--	--	--	15.4	6.2	--	--	--	2.5	12.2	--	.6	435
	9	100.0	--	--	--	--	--	--	--	--	--	--	--	--	--	1/	18
	10	30.6	--	--	--	--	--	--	17.5	--	--	8.4	--	30.5	13.0	.2	154
	12	81.5	9.3	--	--	--	--	2.6	--	--	--	4.0	2.6	--	--	.8	604
3	4	100.0	--	--	--	--	--	--	--	--	--	--	--	--	--	1/	20
	5	100.0	--	--	--	--	--	--	--	--	--	--	--	--	--	1/	17
	6	38.1	--	19.6	--	--	7.1	6.7	23.9	3.6	--	--	--	--	--	.8	582
	8	--	--	--	100.0	--	--	--	--	--	--	--	--	--	--	1/	28
	12	--	--	100.0	--	--	--	--	--	--	--	--	--	--	--	.1	45
4	4	80.1	--	10.8	--	--	9.1	--	--	--	--	--	--	--	--	.2	176
	6	26.0	4.7	7.9	3.6	--	2.8	14.5	33.7	1.4	--	--	--	--	--	4.1	2,900
	8	12.4	16.9	19.8	15.6	16.9	8.4	--	--	--	--	--	--	--	--	.5	379
	12	74.1	--	--	--	--	--	25.9	--	--	--	--	--	--	--	.3	216
5	6	18.0	7.4	5	--	1.8	--	19.3	43.7	6.0	--	--	--	--	--	1.5	1,085
	8	100.0	--	--	--	--	--	--	--	--	--	--	--	--	--	.1	67
6	6	29.7	2.	4.4	1.8	1.0	5.1	21.5	21.4	12.2	--	--	--	--	--	14.2	9,960
	7	17.6	--	4..	--	8.1	8.5	34.2	24.9	2.5	--	--	--	--	--	2.3	1,631
	8	34.8	4.3	10.8	1.2	1.6	4.9	20.8	15.7	6.9	--	--	--	--	--	24.0	16,873
	9	38.3	--	--	--	--	19.1	27.7	4.3	10.6	--	--	--	--	--	1.8	1,269
	10	45.7	4.9	7.3	4.5	1.4	3.5	14.1	13.1	5.2	--	--	--	--	--	17.7	12,411
	11	30.8	--	1.8	--	--	--	10.9	31.8	23.7	--	--	--	--	--	3.3	2,321
	12	51.6	1.4	8.0	1.4	1.4	5.8	18.9	6.3	5.2	--	--	--	--	--	14.3	10,068
	13	--	--	--	--	--	--	16.4	23.7	57.9	--	--	--	--	--	.7	494
	14	52.7	--	--	4.2	3.2	--	21.1	16.9	1.9	--	--	--	--	--	6.2	4,382
	15	--	--	--	--	--	--	100.0	--	--	--	--	--	--	--	.6	390
	16	89.8	--	--	--	--	--	--	10.2	--	--	--	--	--	--	1.3	944
	18	66.7	--	33.3	--	--	--	--	--	--	--	--	--	--	--	.4	324
	20	59.1	--	40.9	--	--	--	--	--	--	--	--	--	--	--	.6	440
9	9	--	--	--	--	--	--	50.2	24.9	--	--	--	--	--	--	.5	377
Total		28,920	1,910	5,049	1,491	1,289	1,917	12,855	10,957	4,787	--	205	138	157	37	100.0	70,712

1/ Percentage is less than 0.05.

Table 15.--The distribution of study lumber by PLIB grade, thickness, and width for No. 1 logs

Thickness	Width	No. 2 Clear	No. 3 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 3 Common	Factory Select	No. 1	No. 2 Shop						
1	4	61.8	7.2	[illegible]	--	--	[illegible]	--	[illegible]	--	--	[illegible]	[illegible]	[illegible]	--	0.2
	6	55.9	--	[illegible]	--	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]	--	.4
	8	83.6	[illegible]	10.5	--	--	--	--	--	--	--	5.9	[illegible]	[illegible]	[illegible]	[illegible]
	12	100.0	--	--	--	--	[illegible]	--	--	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]
2	4	68.6	4.4	[illegible]	--	--	[illegible]	[illegible]	[illegible]	--	--	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	6	100.0	--	--	--	--	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]
	8	66.6	2.4	2.3	--	[illegible]	--	--	--	--	--	[illegible]	10.1	4.7	[illegible]	[illegible]
	8	61.3	--	6.3	--	--	--	--	--	--	3.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	10	[illegible]	9.9	[illegible]	--	--	[illegible]	[illegible]	[illegible]	--	--	[illegible]	7.6	6.	[illegible]	[illegible]
	12	60.0	[illegible]	[illegible]	--	--	--	--	[illegible]	--	--	10.9	[illegible]	[illegible]	[illegible]	[illegible]
	14	--	--	--	[illegible]	[illegible]	[illegible]	100.0	[illegible]	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]
3	4	[illegible]	--	--	--	[illegible]	[illegible]	[illegible]	20.7	[illegible]	--	--	[illegible]	[illegible]	[illegible]	[illegible]
	5	--	--	--	--	[illegible]	[illegible]	--	100.0	--	--	--	[illegible]	[illegible]	--	[illegible]
	6	39.5	2.0	8.6	5.4	[illegible]	4.6	13.2	12.9	9.5	--	[illegible]	--	--	[illegible]	[illegible]
	8	100.0	--	--	--	[illegible]	[illegible]	--	--	--	--	[illegible]	--	[illegible]	[illegible]	[illegible]
	10	--	[illegible]	[illegible]	--	[illegible]	--	--	100.0	[illegible]	[illegible]	--	[illegible]	--	[illegible]	[illegible]
4	4	31.8	--	8.9	20.2	9.3	7.7	4.1	9.6	[illegible]	6.0	--	[illegible]	--	--	[illegible]
	5	68.9	--	31.1	--	--	--	--	--	--	--	--	--	--	--	[illegible]
	6	[illegible]	2.6	[illegible]	[illegible]	2.7	3.2	[illegible]	[illegible]	[illegible]	.3	--	--	--	[illegible]	[illegible]
	8	35.3	--	14.2	17.3	6.1	7.4	9.3	10.4	--	--	--	--	--	--	[illegible]
	10	35.5	--	44.3	--	[illegible]	9.2	--	--	--	--	--	--	--	--	[illegible]
	12	100.0	--	[illegible]	--	--	[illegible]	--	--	--	--	--	[illegible]	--	--	[illegible]
	13	63.0	--	--	37.0	--	[illegible]	[illegible]	--	--	--	[illegible]	[illegible]	--	--	[illegible]
	14	50.0	--	50.0	--	--	[illegible]	[illegible]	--	--	--	[illegible]	[illegible]	--	--	[illegible]
	16	100.0	--	--	--	[illegible]	[illegible]	[illegible]	--	--	--	--	[illegible]	--	[illegible]	[illegible]
5	5	66.7	--	--	--	--	--	--	33.3	--	--	--	--	--	--	[illegible]
	6	6.5	--	[illegible]	--	--	3.8	34.3	38.8	[illegible]	[illegible]	[illegible]	[illegible]	--	--	[illegible]
	8	39.6	--	16.3	--	--	23.3	--	20.8	--	--	--	[illegible]	--	--	[illegible]
6	6	16.3	3.0	8.0	4.1	3.8	9.3	15.8	26.2	12.8	.7	[illegible]	--	[illegible]	--	11.7
	7	3.8	--	1.7	3.3	[illegible]	5.9	36.8	[illegible]	17.3	[illegible]	--	--	--	--	2.8
	8	16.6	3.9	19.6	7.9	[illegible]	6.9	[illegible]	17.8	6.3	.5	--	[illegible]	--	--	27.3
	9	4.8	1.2	[illegible]	[illegible]	1.2	5.0	22.6	[illegible]	[illegible]	--	--	--	--	[illegible]	3.2
	10	23.0	4.4	19.6	4.4	5.2	5.7	14.4	16.0	6.8	.5	--	--	--	[illegible]	21.1
	11	10.9	--	[illegible]	6.7	--	9.2	10.9	[illegible]	[illegible]	--	--	[illegible]	--	[illegible]	[illegible]
	12	29.6	4.6	11.0	2.9	1.9	[illegible]	21.2	17.2	6.3	--	--	--	--	--	[illegible]
	13	--	--	--	--	--	41.7	45.8	--	12.5	--	--	--	--	[illegible]	.4
	14	48.1	3.1	[illegible]	[illegible]	1.7	4.8	23.3	10.7	2.3	--	--	--	--	[illegible]	5.0
	15	[illegible]	21.4	--	--	[illegible]	--	--	35.7	--	--	--	--	[illegible]	--	.6
	16	40.6	--	--	--	15.1	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	1.2
	17	100.0	--	--	--	--	--	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]
	18	80.6	9.0	--	--	--	--	[illegible]	--	--	--	--	--	--	--	[illegible]
	20	100.0	--	--	--	--	--	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]
7	8	100.0	--	--	--	--	--	--	--	--	[illegible]	--	[illegible]	--	--	[illegible]
9	10	--	50.0	50.0	--	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	10	--	--	90.0	--	[illegible]	--	[illegible]	[illegible]	--	--	--	--	[illegible]	--	[illegible]
	12	--	--	100.0	--	--	--	--	--	--	--	--	--	--	--	[illegible]
								Board feet								
Total		35,272	5,127	20,038	[illegible]	[illegible]	8,927	22,862	27,372	10,724	578	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1/ Percentage is less than 0.05.

Table 16.—The distribution of study lumber by PLIB grade, thickness, and width for No. 2 logs

Thickness	Width	No. 2 Clear	No. 3 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 3 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	Construction	Standard	Utility	Economy	Lumber volume	
																Percent	Board feet
Inches								*Percent*									
1	4	35.8	1.0	22.0	--	--	--	--	-	--	--	16.4	12.9	11.1	0.8	0.1	396
	6	56.9	--	.9	-	--	--	--	--	--	--	21.2	9.6	10.2	1.2	.1	750
	8	39.8	--	5.9	--	--	--	--	--	--	--	19.5	28.0	6.8	--	1/	118
	10	100.0	--	--	--	--	--	--	--	--	--	--	--	--	--	1/	17
	12	46.2	--	--	--	--	--	--	--	--	--	--	--	--	53.8	1/	26
2	3	--	-	--	--	-	--	-	--	--	--	100.0	--	--	--	1/	10
	4	35.6	1.2	8.1	--	--	--	--	--	--	--	27.3	11.6	13.4	2.8	.2	1,376
	6	46.4	2.9	4.3	--	-	--	1.5	1.4	--	--	20.6	9.1	11.1	2.8	.5	2,934
	8	42.3	6.6	8.2	-	--	--	2.4	2.8	--	--	22.6	6.5	7.5	1.8	.2	1,432
	9	--	--	--	--	--	--	--	--	--	--	100.0	—	--	--	1/	21
	10	69.1	--	--	--	-	--	--	--	--	--	25.6	5.3	--	--	.1	430
	12	43.6	4.5	-	--	--	--	-	3.2	--	--	19.5	10.4	18.8	--	.1	616
3	6	17.6	-	10.0	7.2	11.4	10.4	10.9	25.9	4.3	2.4	--	--	--	--	.3	1,959
	7	--	--	-	100.0	--	--	-	-	--	--	--	--	--	--	1/	24
	8	17.0	--	45.6	22.8	8.6	9.2	3.3	3.3	--	--	--	--	--	--	.2	1,224
	10	3.0	--	47.6	35.8	10.6	--	--	3.0	--	--	--	--	--	--	.2	990
	12	37.1	--	--	62.9	--	--	--	--	--	--	--	--	--	--	1/	210
	18	-	--	100.0	--	--	--	--	--	--	--	--	--	--	--	1/	54
4	4	15.2	3.1	27.2	12.0	8.4	11.8	5.2	12.6	2.6	1.9	--	--	--	--	.2	1,017
	5	18.6	--	10.6	-	22.2	8.8	11.4	17.8	10.6	--	--	--	--	--	.1	376
	6	9.1	.3	30.7	12.7	13.0	14.3	9.0	26.3	4.4	--	--	--	--	--	2.2	12,204
	7	-	--	37.8	13.4	22.0	26.8	--	--	--	--	--	--	--	--	1/	209
	8	8.1	--	26.9	28.3	17.4	9.0	3.3	2.7	4.3	--	--	--	--	--	1.1	6,395
	9	-	--	--	45.4	14.5	20.8	--	--	19.3	--	--	-	--	--	.1	288
	10	4.0	-	33.1	24.3	20.8	9.0	3.6	3.2	--	--	--	--	--	--	.6	3,315
	11	--	--	100.0	--	--	--	--	--	--	--	--	--	--	--	1/	73
	12	5.4	--	40.9	34.6	29.1	--	--	--	--	--	--	--	--	--	.3	1,760
	13	-	--	45.5	54.5	--	--	--	--	--	--	--	--	--	--	1/	191
	14	--	--	21.8	78.2	--	--	--	--	--	--	--	--	--	--	.2	859
	16	10.7	--	56.6	33.5	9.2	--	--	--	--	--	--	--	--	--	.2	1,397
	18	--	--	--	100.0	--	--	--	--	--	--	--	--	--	--	1/	72
5	5	-	-	100.0	--	--	--	--	--	--	--	--	--	--	--	1/	37
	6	5.7	1.4	12.0	6.8	4.8	9.2	15.6	31.9	13.0	--	--	--	--	--	1.1	6,390
	7	--	--	61.3	22.8	15.9	--	--	--	--	--	--	--	--	--	.1	333
	8	4.7	1.8	27.9	23.7	13.3	15.1	6.7	4.5	2.3	--	--	--	--	--	.6	3,406
	10	2.8	--	46.6	20.5	15.6	9.2	--	3.2	2.1	--	--	--	--	--	.4	2,359
	11	-	--	--	-	100.0	--	--	--	--	--	--	--	--	--	1/	55
	12	--	--	34.1	46.4	19.5	--	--	--	--	--	--	--	--	--	.2	1,230
	14	--	-	40.6	43.8	--	15.6	--	--	--	--	--	--	--	--	.1	747
	16	--	--	29.7	45.5	11.9	12.9	--	--	--	--	--	--	--	--	.2	1,346
6	6	9.2	1.1	12.6	7.9	9.6	13.9	10.8	21.5	13.4	--	--	--	--	--	9.9	56,028
	7	3.6	.5	8.7	6.2	10.0	14.7	12.7	30.1	13.5	--	--	--	--	--	3.1	17,473
	8	10.1	1.9	23.9	11.4	11.5	12.5	9.4	12.2	7.0	.1	--	--	--	--	27.0	151,432
	9	1.1	.7	14.5	6.8	6.4	11.7	10.8	32.1	15.5	.4	--	--	--	--	3.7	20,782
	10	7.2	1.3	29.1	12.9	14.0	11.2	8.1	11.5	4.9	.2	--	--	--	--	21.4	119,720
	11	2.1	--	8.6	5.4	3.6	8.1	20.6	41.5	9.4	.7	--	--	--	--	2.0	11,231
	12	12.6	2.2	20.9	14.5	12.4	5.3	13.1	14.0	4.8	.2	--	--	--	--	9.5	53,796
	13	5.8	--	11.5	13.3	11.7	8.5	4.6	34.7	9.9	--	--	--	--	--	1.1	6,449
	14	10.9	1.2	16.4	17.2	15.0	6.2	14.2	13.7	6.2	--	--	--	--	--	4.9	27,685
	15	--	--	23.8	6.4	1.7	-	5.4	47.8	14.9	--	--	--	--	--	.9	5,220
	16	9.1	--	20.6	10.7	17.2	2.9	6.2	26.4	6.9	--	--	--	--	--	2.8	15,552
	17	6.5	--	12.5	7.1	2.7	3.3	3.3	49.1	15.5	--	--	--	--	--	1.1	6,256
	18	7.8	--	14.6	18.9	4.3	2.2	3.9	37.7	10.6	--	--	--	--	--	1.5	8,280
	19	--	--	34.0	12.4	--	--	10.3	37.1	6.2	--	--	--	--	--	.3	1,843
	20	--	--	49.4	32.2	-	11.5	--	--	6.9	--	--	--	--	--	.3	1,740
7	8	--	--	--	40.5	--	--	--	38.3	21.2	--	--	--	--	--	.1	438
	10	--	--	--	--	100.0	--	--	--	--	--	--	--	--	--	1/	117
8	8	--	--	--	--	--	--	--	100.0	--	--	--	--	--	--	1/	128
	9	--	--	--	50.0	50.0	--	--	--	--	--	--	--	--	--	1/	240
	10	--	--	52.4	--	--	--	--	23.8	23.8	--	--	--	--	-	.1	559
9	9	--	--	71.0	--	--	29.0	--	--	--	--	--	--	--	--	.2	931
	10	--	--	75.0	25.0	--	--	--	--	--	--	--	--	--	--	.1	420
10	10	--	--	66.7	33.3	--	--	--	--	--	--	--	--	--	--	.2	1,050
	12	--	--	50.0	50.0	--	--	--	--	--	--	--	--	--	--	.1	640
								Board feet									
Total		50,066	7,189	12,212	69,479	64,510	57,061	52,778	95,125	41,781	857	1,810	741	885	162	100.0	564,656

1/ Percentage is less than 0.05.

Table 17.—The distribution of study lumber by PLIB grade, thickness, and width for No. 3 logs

Thickness	Width	No. 2 Clear	No. 3 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 3 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	Construction	Standard	Utility	Economy	Board Feet Scaled
Inches								*Percent*								
1	4	12.0	1.0	11.0	--	--	--	-	--	--	--	[illegible]	19.2	[illegible]	5.1	0.1	[illegible]
	6	36.6	--	--	--	--	--	--	--	--	-	[illegible]	[illegible]	[illegible]	--	1/	[illegible]
	8	23.9	--	--	--	--	--	--	--	--	--	-	50.0	[illegible]	--		[illegible]
2	4	12.0	6.9	21.7	--	--	--	--	--	--	-	[illegible]	17.4	[illegible]	3.0	-	[illegible]
	6	9.5	--	9.8	-	-	--	--	--	--	-	[illegible]	[illegible]	[illegible]	[illegible]	.3	[illegible]
	8	8.4	--	15.9	--	-	--	2.9	9.1	-	-	41.9	[illegible]	12.0	--	.4	[illegible]
	10	29.1	--	31.6	--	-	--	15.7	--	-	-	23.6	--	--	--	.1	[illegible]
	12	60.0	--	--	--	--	--	--	--	--	--	[illegible]	--	--	--	.1	[illegible]
3	4	--	--	--	--	100.0	--	--	--	--	--	--	--	--	--		[illegible]
	6	--	--	-	100.0	-	-	--	--	--	--	[illegible]	--	--	--	1/	[illegible]
	8	-	--	16.1	28.5	33.8	21.6	--	--	--	--	[illegible]	--	--	--	.4	[illegible]
	8	--	--	32.8	11.9	19.9	5.4	--	--	--	--	[illegible]	--	--	--	.3	[illegible]
	10	--	--	32.4	31.5	36.1	--	--	--	-	--	[illegible]	--	--	--	.2	[illegible]
4	4	6.1	-	7.9	43.4	21.8	17.0	--	--	3.8	--	--	--	[illegible]	-	.3	[illegible]
	5	50.0	--	--	50.0	--	--	--	--	--	--	--	--	[illegible]	-	-	[illegible]
	6	2.1	.5	14.7	24.6	22.5	24.6	--	5.4	5.6	--	[illegible]	--	[illegible]	-	[illegible]	[illegible]
	7	--	--	--	23.0	77.0	--	--	--	--	--	--	-	-	-	1/	[illegible]
	8	.6	--	17.5	28.8	34.7	11.9	--	4.6	1.9	--	--	-	[illegible]	--	[illegible]	[illegible]
	9	--	--	--	--	100.0	--	--	--	--	--	--	[illegible]	[illegible]	-	1/	[illegible]
	10	--	--	37.1	27.4	24.0	10.6	-	.9	--	--	[illegible]	--	[illegible]	--	1.9	[illegible]
	11	--	-	--	--	--	--	--	--	100.0	--	[illegible]	--	--	--	1/	[illegible]
	12	--	--	13.2	42.3	35.0	9.5	-	-	--	-	[illegible]	[illegible]	[illegible]	[illegible]	1.0	[illegible]
	14	--	--	26.5	26.5	47.0	--	--	--	--	--	--	--	[illegible]	[illegible]	.3	[illegible]
	16	--	--	31.2	37.6	31.2	--	--	--	-	--	--	--	[illegible]	[illegible]	..	[illegible]
5	5	--	-	--	25.3	37.7	19.9	--	17.1	-	--	--	--	--	--	.1	[illegible]
	6	--	--	20.3	8.1	23.3	15.0	--	18.0	15.3	--	[illegible]	--	--	--	.7	1,600
	7	--	--	--	31.0	--	45.3	--	--	23.7	--	--	--	[illegible]	--	.1	[illegible]
	8	2.2	--	29.5	35.1	22.0	11.2	--	--	--	--	[illegible]	--	--	--	.8	1,787
	9	--	--	--	--	100.0	--	--	--	--	--	[illegible]	[illegible]	[illegible]	--	1/	[illegible]
	10	--	--	29.5	32.7	37.8	--	-	--	--	--	--	--	--	--	.8	1,908
	12	--	--	--	61.9	38.1	--	--	--	--	--	--	--	[illegible]	--	.1	[illegible]
	14	--	--	--	--	62.6	37.4	--	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]	.1	187
6	6	1.6	--	8.4	15.5	18.9	30.8	3.2	8.2	12.4	1.0	--	--	-	--	11.8	26,600
	7	1.5	--	6.4	17.5	20.6	28.4	3.3	11.3	11.0	--	--	--	--	-	2.8	6,381
	8	2.3	.6	10.7	19.8	24.9	23.2	3.0	7.8	7.5	.2	--	--	--	--	25.3	56,921
	9	--	--	9.4	15.5	12.6	28.6	2.1	25.2	6.6	--	--	--	--	--	3.5	7,897
	10	1.5	--	13.6	19.6	25.8	22.0	4.0	6.8	6.5	.2	--	--	--	--	23.4	52,740
	11	--	--	5.7	6.7	20.7	16.0	11.0	28.5	11.4	--	--	--	--	--	1.5	3,289
	12	2.2	1.2	13.5	18.7	25.3	11.8	6.3	13.4	7.0	.6	--	--	--	--	8.4	18,900
	13	--	--	6.4	21.3	34.3	--	30.3	7.7	--	--	--	--	--	--	.9	2,015
	14	--	--	6.7	31.7	29.7	17.0	4.6	3.9	6.4	--	--	--	--	-	2.7	6,076
	15	--	--	--	--	30.3	13.9	26.7	29.1	--	--	-	-	--	--	.6	1,340
	16	--	4.7	10.7	16.6	24.1	15.0	2.4	19.4	7.1	--	--	--	--	--	1.8	4,048
	17	--	--	31.2	--	--	--	-	68.8	--	--	--	--	--	--	.2	544
	18	--	--	19.3	48.5	17.7	4.8	--	9.7	--	--	--	--	-	[illegible]	1.0	2,232
	19	--	--	--	100.0	--	--	--	--	--	--	-	--	--	--	.1	228
	20	38.9	--	61.1	--	--	--	-	--	--	--	--	--	--	--	.2	360
7	8	--	--	30.4	--	69.6	--	--	--	--	--	--	-	-	--	.1	214
8	8	--	--	--	39.9	60.1	--	--	--	--	--	--	--	--	--	.2	424
	10	--	--	50.0	50.0	--	--	--	--	--	--	--	--	--	--	..	188
	12	--	--	--	--	--	100.0	--	--	--	--	-	--	--	-	.1	111
9	9	--	--	--	80.1	--	19.9	--	--	--	--	--	--	--	--	.2	472
	10	--	--	--	50.0	--	50.0	--	--	--	--	--	-	--	--	.1	210
10	10	--	--	28.6	28.6	14.3	28.5	--	--	--	--	--	--	-	--	.4	810
									Board feet								
Total		4,055	649	27,994	45,830	53,824	46,918	6,977	19,912	16,017	606	886	480	436	117	100.0	234,791

1/ Percentage is less than 0.05.

Table 18.—The distribution of study lumber by PLIB grade, thickness, and width for all grade logs

Thickness	Width	No. 2 Clear	No. 3 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 3 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	Construction	Standard	Utility	Economy	Lumber volume: Percent	Lumber volume: Board feet
1		--	--	--	--	--	--	--	--	-	--	--	--	100.0	--	1/	3
	4	40.1	2.6	1.2	--	--	--	--	--	--	--	15.8	13.3	13.1	2.9	0.1	1,054
	6	60.0	.3	.6	--	--	--	--	--	--	--	22.3	6.1	10.0	.5	.2	1,768
	8	59.0	3.0	8.7	--	--	--	--	--	--	--	8.7	15.2	5.4	—	1/	369
	10	100.0	--	--	--	--	--	--	--	--	--	--	--	--	--	1/	17
	12	61.2	--	--	--	--	--	--	--	-	--	--	--	--	36.8	1/	38
2	4	--	--	--	--	--	--	--	--	--	--	100.0	--	--	--	1/	10
	6	43.5	4.4	8.7	--	--	--	--	--	--	--	19.5	10.0	12.1	1.8	.3	3,131
	8	100.0	--	--	--	--	--	--	--	--	--	--	--	--	--	1/	12
	10	53.8	1.9	3.6	--	--	0.4	0.7	--	--	--	18.5	9.9	7.8	2.9	.6	6,153
	12	100.0	-	--	--	--	-	--	--	--	--	--	--	--	--	1/	14
	8	34.1	2.7	9.4	--	--	3.0	2.7	0.7	-	-	23.8	8.4	8.8	.4	.4	3,560
	9	46.2	--	-	--	-	--	--	--	-	-	53.8	--	--	--	1/	39
	10	60.4	3.7	1.7	--	--	1.7	2.4	--	--	--	13.3	2.9	8.4	1.7	.1	1,147
	12	61.5	4.6	--	-	-	.9	2.6	—	-	-	14.3	8.7	7.4	--	.2	1,840
	14	--	--	--	--	--	100.0	--	--	--	--	--	--	--	--	1/	33
3	4	20.9	-	--	--	16.7	--	20.9	12.5	27.0	-	--	--	--	--	1/	90
	5	29.8	--	--	40.4	-	--	--	29.8	--	--	--	--	--	--	1/	57
	6	21.8	.3	12.1	10.1	1.8	10.4	8.7	18.0	4.5	1.1	--	--	--	--	.4	4,503
	7	--	--	--	100.0	--	--	--	--	--	--	--	--	--	--	1/	24
	8	11.7	--	33.6	30.6	12.6	7.5	2.0	2.0	--	--	--	--	--	--	.2	2,024
	10	1.9	--	4.9	32.6	18.8	--	-	4.0	--	--	--	--	--	--	.2	1,610
	12	37.1	--	--	62.9	--	--	--	--	--	--	--	—	--	--	1/	210
	18	--	--	100.0	-	--	--	--	--	--	--	--	—	--	--	1/	54
4	4	21.4	1.1	16.0	17.1	11.7	12.0	3.1	7.5	2.7	2.3	--	--	--	--	.2	2,563
	5	31.5	--	13.8	4.4	15.7	6.2	8.1	12.7	7.6	--	--	--	—	--	1/	528
	6	13.9	1.3	10.5	13.3	12.7	13.6	8.0	22.1	4.5	1.1	--	—	--	--	2.8	27,869
	7		-	23.9	16.9	42.3	--	--	16.9	--	--	--	--	--	—	1/	331
	8	7.2	.5	22.0	27.3	23.8	10.1	2.3	3.9	2.9	--	--	—	--	--	1.3	12,975
	9	--	--	--	33.3	37.4	15.2	--	--	13.6	--	--	--	--	--	1/	396
	10	3.6	--	37.3	24.6	21.3	9.9	1.5	1.8	--	--	--	—	--	--	.8	8,036
	11	--	--	45.3	--	--	--	--	--	54.7	--	--	--	--	--	1/	161
	12	14.4	--	18.3	33.6	27.9	4.6	1.2	--	--	--	--	--	--	--	.4	4,552
	13	29.2	--	24.4	46.4	—	--	--	--	--	--	--	--	--	--	1/	356
	14	6.0	--	27.1	47.3	19.6	--	--	-	--	--	--	--	--	--	.2	1,857
	16	14.8	--	40.6	32.0	12.6	--	--	--	--	--	--	--	—	—	.2	1,867
	18	--	--	--	100.0	--	--	-	--	--	--	--	--	--	--	1/	72
5	5	19.4	--	14.4	14.4	21.1	11.3	--	19.4	--	--	--	--	--	--	1/	257
	6	6.2	1.5	11.0	5.1	6.7	8.3	16.5	32.0	12.7	--	--	--	--	--	1.1	10,835
	7	--	--	35.3	20.3	9.2	19.2	--	--	10.0	--	--	--	--	--	.1	578
	8	6.9	1.1	28.0	25.8	15.2	14.0	4.1	3.8	1.4	--	--	--	—	—	.6	5,547
	9	--	--	--	--	100.0	--	--	--	--	--	--	--	--	--	1/	75
	10	1.6	--	39.2	25.8	25.2	5.2	--	1.8	1.2	--	--	--	--	—	.4	4,167
	11	-	--	--	--	100.0	--	--	--	--	--	--	—	--	--	1/	55
	12	--	--	17.4	54.0	28.6	--	--	--	--	--	--	--	--	--	.2	2,410
	14	--	--	32.4	35.1	12.5	20.0	--	--	--	--	--	--	--	--	.1	934
	16	--	--	29.7	45.6	11.9	--	--	12.8	--	--	--	--	--	--	.1	1,346
6	6	10.3	1.2	10.1	8.6	10.3	16.6	10.7	18.9	13.0	.3	--	--	--	--	10.9	109,704
	7	4.0	.3	7.0	7.8	10.7	16.0	15.2	26.1	12.9	--	--	--	--	--	2.9	29,324
	8	11.0	2.0	19.6	12.0	12.9	13.5	9.5	12.3	7.0	.2	--	--	--	—	26.5	264,324
	9	2.7	.6	11.3	8.8	6.9	14.9	11.0	29.7	13.8	.2	--	--	—	—	3.4	34,543
	10	10.3	1.6	22.6	12.6	14.9	12.6	8.4	11.1	5.6	.3	--	--	--	--	21.6	215,525
	11	6.3	--	6.8	5.1	5.6	8.6	16.5	38.2	11.9	.4	--	--	--	--	1.9	19,470
	12	17.4	2.3	16.6	12.1	12.0	9.6	13.7	13.6	5.5	.2	--	--	--	--	9.8	99,048
	13	3.9	--	7.7	10.3	12.3	13.6	7.0	31.1	12.1	--	--	--	--	--	1.0	9,582
	14	20.6	.9	11.4	15.6	13.7	6.8	14.4	12.2	5.2	--	--	--	—	—	4.5	45,367
	15	4.6	2.3	14.1	4.3	6.2	2.3	8.7	40.6	14.9	--	--	--	--	—	.8	7,740
	16	14.1	--	16.3	10.5	17.6	5.5	5.2	24.3	6.5	--	--	--	--	--	2.2	22,240
	17	9.4	-	13.5	6.4	2.4	2.9	2.9	48.9	13.7	--	--	--	--	--	.7	7,055
	18	11.2	.9	14.5	22.0	6.4	2.4	3.7	27.7	7.3	--	--	--	--	--	1.2	12,042
	19	--	--	30.3	22.0	—	--	9.2	33.0	5.5	--	--	--	--	--	.2	2,071
	20	20.7	--	43.4	19.2	--	6.8	--	--	4.1	--	--	--	--	--	.3	2,920
7	8	7.9	--	9.2	25.1	21.0	--	--	23.7	13.1	--	--	--	--	--	.1	708
	10	--	--	—	--	100.0	--	--	--	--	--	--	--	--	--	1/	240
8	8	-	--	--	29.7	44.8	--	--	25.5	--	--	--	--	--	--	1/	501
	9	--	--	--	50.0	50.0	--	--	--	--	--	--	--	--	--	1/	240
	10	--	--	51.9	12.5	--	--	--	17.8	17.8	--	--	--	--	--	.1	745
	12	--	--	-	--	--	100.0	--	--	--	--	--	--	--	--	1/	112
9	9	--	--	42.5	21.2	--	20.4	10.6	5.3	--	--	--	--	--	--	.2	1,780
	10	--	--	62.5	25.0	-	12.5	--	--	--	--	--	--	--	--	.1	840
10	10	--	--	65.4	19.2	7.7	7.7	--	--	--	--	--	--	--	—	.3	3,033
	12		--	62.8	37.2	--	--	--	--	--	--	--	--	--	—	.1	860
								Board feet									
Total		118,911	14,875	175,293	124,024	135,488	115,823	95,472	153,366	73,309	2,041	3,635	1,722	1,745	324	100.0	1,005,424

1/ Percentage is less than 0.05.

Table 19.—The distribution of study lumber by PLIB grade and length for Select logs

Board length (feet)	No. 2 Clear	No. 3 Clear	Select Merchant-able	No. 1 Merchant-able	No. 2 Merchant-able	No. 3 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Lumber value
																Per cent
8	82.1	--	3.9	5.6	3.6	-	[illegible]	3.8	--	--	2.9	[illegible]	[illegible]	--	[illegible]	[illegible]
10	83.[illegible]	[illegible]	[illegible]	--	--	8.2	[illegible]	6.7	[illegible]	[illegible]	4.8	.5	[illegible]	[illegible]	1.4	[illegible]
12	47.9	3.5	4.3	1.2	2.8	4.7	14.7	12.2	[illegible]	[illegible]	.5	[illegible]	[illegible]	[illegible]	20.5	[illegible]
14	47.9	3.4	4.4	.8	.7	1.8	[illegible]	10.4	[illegible]	[illegible]	.4	.2	[illegible]	[illegible]	[illegible]	[illegible]
16	47.5	1.4	1.4	--	--	[illegible]	15.5	[illegible]	[illegible]	[illegible]	--	1.0	1.0	.5	5.1	[illegible]
18	46.3	1.0	8.4	.8	--	4.1	14.9	17.4	[illegible]	-	[illegible]	-	[illegible]	[illegible]	14.6	[illegible]
20	36.7	4.3	7.1	.4	[illegible]	3.2	16.1	21.1	5.[illegible]	[illegible]	.2	[illegible]	[illegible]	[illegible]	16.1	[illegible]
22	30.8	--	30.2	16.4	[illegible]	7.5	15.1	[illegible]	[illegible]	-	--	[illegible]	[illegible]	--	[illegible]	[illegible]
24	14.6	3.0	11.0	3.8	3.2	8.7	24.8	[illegible]	7.4	[illegible]	[illegible]	[illegible]	--	[illegible]	[illegible]	[illegible]
26	23.3	--	[illegible]	6.8	1.3	2.1	19.1	15.1	9.[illegible]	--	--	--	[illegible]	[illegible]	11.3	7,982
								Board feet								
Total	28,920	1,910	4,049	1,491	1,289	2,917	12,855	10,957	[illegible]	--	[illegible]	[illegible]	147	[illegible]	[illegible]	[illegible]

Table 20.—The distribution of study lumber by PLIB grade and length for No. 1 logs

Board length (feet)	No. 2 Clear	No. 3 Clear	Select Merchant-able	No. 1 Merchant-able	No. 2 Merchant-able	No. 3 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Lumber value
																Per cent
6	100.0	--	--	--	--	[illegible]	-	--	[illegible]	--	[illegible]	-	--	-	1/	[illegible]
8	49.0	4.1	2.0	--	-	[illegible]	11.6	6.7	10.2	[illegible]	8.1	4.1	1.[illegible]	--	[illegible]	[illegible]
10	51.4	1.0	4.1	4.1	--	8.1	13.0	[illegible]	[illegible]	-	[illegible]	[illegible]	5.1	--	.8	1,227
11	100.0	--	--	--	--	--	--	--	--	--	[illegible]	--	[illegible]	1/	1/	6
12	33.7	4.1	4.8	3.4	2.8	7.9	16.6	16.5	[illegible]	1/	1.1	.2	[illegible]	[illegible]	16.5	23,963
14	35.2	3.9	12.4	1.3	2.[illegible]	3.8	[illegible]	17.3	[illegible]	1.1	.4	.4	.1	[illegible]	15.3	22,152
16	43.2	.7	15.0	8.6	--	4.3	8.9	12.9	[illegible]	[illegible]	1.1	1.4	1.8	[illegible]	1.5	[illegible]
18	35.2	3.9	11.9	6.2	[illegible]	6.8	16.2	[illegible]	[illegible]	.6	.6	.2	1/	[illegible]	14.6	21,096
20	14.8	3.7	19.6	6.1	5.8	6.6	[illegible]	17.5	[illegible]	.3	.1	.2	.1	-	33.7	48,895
22	21.7		34.1	3.2	--	3.2	[illegible]	[illegible]	[illegible]	--	1.2	—	.5	-	1.9	2,773
24	20.0	4.6	16.2	7.7	7.6	4.5	8.7	[illegible]	8.9	--	--	.1	--	--	[illegible]	12,586
26	19.2	--	[illegible]	5.4	3.0	5.7	20.3	27.2	[illegible]	--	--	-	--	--	[illegible]	[illegible]
28	--	--	-	--	-	[illegible]0.0	-	[illegible]	[illegible]	--	[illegible]	[illegible]	--	-	.1	140
								Board feet								
Total	35,272	5,127	20,038	7,224	[illegible],899	8,927	22,862	27,372	10,724	[illegible]78	7[illegible]	963	267	-	[illegible]	[illegible]

1/ Percentage is less than 0.05.

Table 21.—The distribution of study lumber by PLIB grade and length for No. 2 logs

Board length (feet)	No. 2 Clear	No. 4 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 4 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	Construction	Standard	Utility	Economy	Lumber volume Percent	Lumber volume Board feet
							Percent									
6	50.0	--	-		--	--	--	--	50.0	--	--	--	--	--	1/	18
8	40.0	0.6	2.2	4.1	3.3	6.5	6.2	8.6	4.2	--	7.7	7.1	3.9	0.6	0.2	1,344
10	31.0	.3	11.6	5.2	5.4	15.9	9.1	5.5	7.5	--	5.6	2.3	.5	.2	.6	3,444
11	100.0	--	--	--	--	--	--	--	--	--	--	--	--	--	1/	44
12	19.1	2.1	12.8	4.6	9.1	19.4	11.7	13.0	11.2	0.1	.6	.3	.4	.1	11.1	62,670
13	100.0	--	--	--	-	-	-	--	--	--	--	--	--	--	1/	52
14	14.6	1.7	14.2	9.0	10.4	12.7	10.3	15.4	9.7	.6	.6	.2	.5	.1	8.4	47,172
16	13.8	2.8	21.2	15.6	13.2	12.9	5.4	7.2	3.3	--	2.0	8.0	1.6	.2	1.6	9,266
18	8.9	2.2	22.2	13.8	10.7	12.7	7.9	13.5	7.2	.4	.3	.1	.1	1/	12.5	70,470
19	61.1	--	38.9	--	-	-	--	--	--	--	--	--	--	--	.1	342
20	5.8	1.0	22.4	12.9	13.5	9.6	8.9	18.9	6.7	.1	.1	.1	1/	--	32.9	185,905
21	--	--	--	--	--	--	100.0	--	--	--	--	--	--	--	1/	63
22	5.7	--	33.6	13.3	14.7	9.1	7.1	10.4	4.3	--	--	.3	.1	--	2.5	14,232
24	1.4	1.0	28.0	14.4	10.8	8.3	5.1	18.0	6.0	.1	.2	1/	1/	--	23.7	133,822
26	8.4	.8	13.8	8.6	11.7	9.8	14.8	22.8	4.5	--	--	--	--	--	6.3	35,492
42	-	--	-	100.0	--	-	--	--	--	--	--	--	--	--	.1	320
							Board feet									
Total	50,666	7,189	122,212	69,479	64,510	57,361	52,778	98,125	41,781	857	1,810	741	885	162	100.0	564,656

1/ Percentage is less than 0.05.

Table 22.—The distribution of study lumber by PLIB grade and length for No. 3 logs

Board length (feet)	No. 2 Clear	No. 4 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 4 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	Construction	Standard	Utility	Economy	Lumber volume Percent	Lumber volume Board feet
							Percent									
8	17.8	0.8	11.3	7.7	11.5	21.5	--	4.6	7.7	--	7.1	2.1	5.6	2.5	0.2	521
10	14.9	--	3.9	8.8	27.0	30.8	--	2.7	--	--	5.5	1.8	3.6	2.0	.6	1,465
11	--	--	--	-	-	--	--	--	--	--	100.0	--	--	--	1/	4
12	4.7	.6	10.2	17.7	20.2	24.4	5.1	6.0	11.5	0.3	.9	.5	.3	.1	11.3	25,426
14	4.5	.9	10.6	20.8	25.1	22.8	3.6	7.1	4.4	--	.7	.5	.3	—	9.3	20,745
16	2.9	.2	5.6	25.9	30.9	17.0	1.7	--	11.6	--	1.1	1.8	.9	.4	2.5	5,520
18	1.3	.4	15.8	16.4	22.8	20.5	4.5	9.4	4.9	.5	.6	.1	.2	.1	14.6	32,863
19	100.0	--	--	--	--	--	--	--	--	--	--	--	--	—	1/	76
20	.8	.2	12.4	20.2	26.2	20.1	3.4	9.3	6.6	.5	.2	.1	1/	1/	31.6	70,915
22	1.1	1.2	11.5	20.4	23.9	26.0	3.0	6.8	6.8	--	.3	--	--	—	3.4	7,583
24	.8	-	13.0	23.9	23.1	18.9	1.5	9.9	8.2	-	.1	--	1/	--	20.0	44,916
26	1.4	-	13.6	15.9	16.3	22.4	4.5	15.9	7.6	--	--	--	.4	--	6.5	14,667
							Board feet									
Total	4,044	649	27,994	45,830	53,824	46,918	6,977	19,912	16,017	606	886	480	442	117	100.0	224,701

1/ Percentage is less than 0.05.

Table 23.—The distribution of study lumber by PLIB grade and length for all logs

Board length (feet)	No. 2 Clear	No. 4 Clear	Select Merchantable	No. 1 Merchantable	No. 2 Merchantable	No. 3 Common	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	Construction	Standard	Utility	Economy	Lumber volume Percent	Lumber volume Board feet
							Percent									
6	59.1	--	--	--	--	--	--	--	40.9	--	--	--	--	--	1/	22
8	41.5	1.3	4.8	6.0	4.0	6.7	7.1	7.5	5.5	0.5	6.9	4.9	3.7	0.7	0.3	2,970
10	35.6	1.2	7.9	5.0	8.1	16.6	7.1	4.4	4.1	--	5.5	2.1	1.9	.5	.7	7,106
11	92.6	--	--	--	--	--	--	--	--	--	7.4	--	—	—	1/	54
12	22.3	2.3	9.9	8.8	9.4	12.1	11.3	12.1	10.3	.1	8.7	.3	.3	.1	12.6	126,472
13	100.0	-	--	--	--	--	--	--	--	--	--	--	--	--	1/	52
14	20.9	.2	11.9	8.7	10.4	11.5	11.7	13.5	7.4	.5	.6	.3	.4	1/	10.2	102,397
16	17.8	1.6	14.3	16.6	15.8	12.0	5.6	6.4	5.8	--	1.5	1.1	1.5	.2	1.8	18,527
18	12.5	1.9	18.1	12.8	11.6	13.6	8.9	13.8	6.4	.4	.4	.1	.1	1/	13.4	134,779
19	68.2	-	31.8	--	--	--	--	--	--	--	--	--	—	--	1/	418
20	7.3	1.3	19.3	13.6	14.8	11.1	9.2	16.7	6.9	.2	.1	.1	1/	1/	31.6	316,879
21	--	--	--	-	--	100.0	--	--	--	--	--	--	--	1/	1/	63
22	7.2	.3	27.0	14.4	15.2	13.4	6.7	10.4	4.9	--	.2	.2	.1	--	2.6	25,754
24	5.7	1.1	23.3	15.5	12.8	10.4	7.5	17.1	6.4	--	.2	-	--	--	20.1	201,484
26	12.4	.3	11.9	9.5	10.7	11.0	13.9	20.8	9.5	--	--	--	—	--	6.7	67,785
28	--	--	--	--	--	100.0	-	--	--	--	--	--	--	--	1/	140
42	--		--	100.0	--	--	--	--	--	--	--	--	--	--	1/	320
							Board feet									
Total	214,913	14,875	175,293	124,904	125,482	115,823	95,472	153,366	73,309	2,041	3,635	1,722	1,745	324	100.0	1,005,424

1/ Percentage is less than 0.05.

APPENDIX II

TABULAR LUMBER YIELD DATA

by

Export Grades

Table 24 —Summary of log scale, Export lumber tally, and cubic volumes by diameter classes—Select logs

Log scaling diameter (inches)	Number of logs	Log scale[1]		Export lumber tally		Cubic volume				
		Gross	Net	Volume	Recovery ratio[2]	Log	Lumber	Lumber recovery ratio[3]	Sawdust	Chippable residue
		Board feet		Board feet	Percent	Cubic feet		Percent	Cubic feet	
30	2	3,040	2,860	3,749	131	472.23	332.77	70	24.22	115.24
31	--	--	--	--	--	--	--	--	--	--
32	2	3,220	2,800	4,400	157	593.07	392.10	66	30.44	170.53
33	1	2,490	2,280	3,110	136	367.30	278.41	76	21.29	67.60
34	1	1,700	1,400	1,877	134	291.20	170.05	58	16.28	104.87
35	4	7,660	6,590	8,381	127	1,393.23	748.53	54	59.63	585.07
36	--	--	--	--	--	--	--	--	--	--
37	--	--	--	--	--	--	--	--	--	--
38	1	2,000	1,730	2,652	153	290.94	235.90	81	18.54	36.50
39	--	--	--	--	--	--	--	--	--	--
40	2	3,770	3,140	3,864	123	805.65	344.39	43	25.90	435.36
41	2	4,450	3,810	4,730	124	1,021.36	421.27	41	32.68	567.41
42	2	5,040	3,800	4,524	119	734.09	405.50	55	31.03	297.56
43	--	--	--	--	--	--	--	--	--	--
44	--	--	--	--	--	--	--	--	--	--
45	2	4,940	4,400	5,612	128	813.27	498.95	61	38.23	276.09
46	1	2,970	2,660	3,218	121	619.73	287.64	46	23.18	308.91
47	1	2,480	2,090	2,758	132	480.03	244.72	51	17.94	217.37
48	1	2,600	2,380	2,796	117	361.68	249.51	69	18.20	93.97
49	2	5,840	5,610	5,710	102	1,036.98	508.27	49	38.42	490.29
50	--	--	--	--	--	--	--	--	--	--
51	1	3,650	2,660	3,607	136	695.26	320.71	46	23.45	351.10
52	--	--	--	--	--	--	--	--	--	--
53	2	6,840	6,060	7,353	121	989.14	652.99	66	57.77	288.38
54	--	--	--	--	--	--	--	--	--	--
55	1	3,400	3,040	3,582	118	599.46	316.88	53	22.47	260.11
Total	28	66,090	57,410	71,923	125	11,564.62	6,408.59	55	489.67	4,666.36

[1] As scaled by the Puget Sound Log Scaling and Grading Bureau in log rafts, Scribner log rule.

[2] Export lumber tally volume as percentage of net scale volume.

[3] Lumber cubic volume as percentage of log cubic volume.

Table 25.—Summary of log scale, Export lumber tally, and cubic volumes by diameter classes—No. 1 logs

Log scaling diameter (inches)	Number of logs	Log scale[1]		Export lumber tally		Cubic volume				
		Gross	Net	Volume	Recovery ratio[2]	Log	Lumber	Lumber recovery ratio[3]	Sawdust	Chippable residue
24	1	860	800	998	125	141.00	88.54	[illegible]	[illegible]	46.05
25	3	3,730	3,670	4,593	125	698.56	408.21	58	29.48	260.87
26	3	4,290	3,700	4,475	121	803.13	400.70	[illegible]	31.88	370.55
27	7	9,520	8,850	10,845	123	1,628.04	967.77	[illegible]	68.51	591.76
28	7	10,760	10,050	10,872	108	2,019.03	972.50	48	78.41	968.12
29	6	8,430	7,800	9,242	118	1,621.17	830.13	51	61.76	729.28
30	8	12,570	11,300	13,504	120	2,186.19	1,204.66	[illegible]	90.25	891.28
31	5	7,820	6,790	8,094	119	1,514.21	721.74	[illegible]	55.07	737.40
32	1	1,560	1,420	930	91	507.81	82.71	16	6.17	418.93
33	4	6,670	5,450	8,212	151	1,218.02	728.61	60	52.12	437.29
34	2	3,300	3,860	3,996	140	505.01	353.86	70	25.46	125.69
35	1	1,750	1,600	1,951	122	334.46	175.42	52	13.56	145.48
36	--	--	--	--	--	--	--	--	--	--
37	1	1,670	1,300	1,993	153	223.35	177.62	80	14.04	31.69
38	2	4,920	3,900	4,966	127	661.78	441.71	67	33.29	186.78
39	1	3,690	3,610	3,555	98	895.34	314.98	35	22.43	557.88
40	2	4,810	3,940	3,527	90	732.97	315.33	43	25.02	392.62
41	2	6,670	6,060	7,477	123	1,248.85	662.44	53	47.54	538.87
42	3	6,880	5,960	8,273	139	1,083.75	734.53	68	55.19	294.03
43	--	--	--	--	--	--	--	--	--	--
44	1	2,590	2,350	3,442	146	560.51	305.18	54	22.54	232.79
45	1	2,860	2,350	3,383	144	398.41	300.26	75	22.06	76.09
46	1	2,580	2,180	2,709	124	331.14	240.44	73	18.52	72.18
47	1	3,520	2,660	3,474	131	493.09	311.95	[illegible]	26.65	154.49
48	1	2,600	1,940	3,037	157	334.10	268.99	81	18.66	46.45
49	2	6,290	5,250	7,214	137	1,325.09	638.73	48	46.01	640.35
50	1	3,040	2,600	2,740	105	520.42	243.24	47	17.13	260.05
51	--	--	--	--	--	--	--	--	--	--
52	1	3,800	3,510	4,189	119	677.89	371.81	55	27.83	278.25
53	2	7,630	3,710	2,339	63	1,207.08	209.19	17	17.45	980.44
54	--	--	--	--	--	--	--	--	--	--
55	1	3,970	3,290	3,977	121	523.26	354.60	68	27.71	140.95
56	1	3,820	3,160	3,436	109	720.26	307.10	43	24.04	389.12
Total	72	142,600	122,060	147,443	121	25,113.92	13,132.95	52	985.24	10,995.73

[1] As scaled by the Puget Sound Log Scaling and Grading Bureau in log rafts, Scribner log rule.

[2] Export lumber tally volume as percentage of net scale volume.

[3] Lumber cubic volume as percentage of log cubic volume.

Table 26.—Summary of log scale, Export lumber tally, and cubic volumes by diameter classes—No. 2 logs

Log scaling diameter (inches)	Number of logs	Log scale[1/]		Export lumber tally		Cubic volume				
		Gross	Net	Volume	Recovery ratio[2/]	Log	Lumber	Lumber recovery ratio[3/]	Sawdust	Chippable residue
		Board feet		Percent		Cubic feet		Percent	Cubic feet	
14	17	5,100	4,960	7,436	150	1,100.15	660.61	60	45.73	393.81
15	25	9,610	9,380	12,665	135	2,069.12	1,122.85	54	78.95	867.32
16	17	11,490	11,130	16,403	147	2,447.93	1,449.86	59	98.89	899.18
17	19	9,280	8,950	11,672	130	1,840.48	1,038.06	56	72.61	729.81
18	37	21,370	20,490	28,769	140	4,339.71	2,538.67	58	166.66	1,634.38
19	24	17,160	16,290	23,050	141	3,170.13	2,034.84	64	134.91	1,000.38
20	20	16,080	15,480	21,068	136	2,822.80	1,857.55	66	122.55	842.70
21	30	25,520	24,710	31,691	128	4,582.35	2,805.64	61	192.81	1,583.90
22	25	21,880	20,690	30,483	147	4,108.03	2,699.10	66	185.41	1,223.52
23	24	21,160	19,800	26,294	133	3,605.92	2,327.38	65	159.25	1,119.29
24	21	23,940	23,060	30,075	130	4,189.01	2,671.14	64	189.78	1,328.09
25	20	24,420	23,530	30,844	131	4,293.02	2,732.82	64	189.47	1,370.73
26	12	14,450	13,110	16,189	123	2,681.09	1,436.76	54	104.61	1,139.72
27	10	13,430	12,440	15,378	124	2,106.24	1,360.76	65	94.35	651.13
28	11	17,440	16,600	20,207	122	2,093.82	1,785.62	58	124.85	1,183.35
29	15	20,670	18,390	25,173	137	3,337.57	2,233.28	67	158.38	945.91
30	12	18,410	15,550	23,802	153	3,499.95	2,114.45	59	150.38	1,335.11
31	7	11,290	9,810	12,483	127	1,976.97	1,112.60	56	84.32	780.05
32	6	9,380	8,730	11,840	136	1,720.77	1,050.18	61	75.97	594.62
33	7	14,240	11,630	15,273	131	2,442.13	1,347.78	55	99.01	995.34
34	8	14,750	13,520	18,944	140	2,319.18	1,677.21	72	118.15	523.82
35	5	10,570	9,570	13,153	137	1,854.07	1,167.92	63	88.37	597.78
36	2	3,810	3,040	4,407	145	604.98	391.38	65	28.07	185.53
37	4	9,280	7,890	10,774	137	1,477.86	957.51	65	71.38	448.97
38	8	17,540	14,170	19,855	140	2,857.70	1,759.89	62	126.50	971.31
39	5	12,450	10,830	13,130	121	2,276.83	1,165.91	51	86.30	1,024.62
40	6	15,480	11,410	15,673	137	2,544.56	1,388.62	55	99.29	1,056.65
41	1	2,540	1,680	2,561	152	343.02	226.84	66	15.43	100.75
42	5	15,150	11,090	14,045	127	2,059.25	1,249.99	61	93.71	715.55
43	3	7,840	6,180	7,347	119	1,033.15	654.09	63	45.26	333.80
44	5	16,720	14,430	17,611	122	3,045.13	1,563.58	51	114.16	1,367.39
45	2	5,330	3,420	4,687	137	695.60	415.11	60	29.74	250.75
46	5	15,070	9,360	12,451	133	2,056.99	1,115.71	54	83.68	857.60
47	1	2,690	2,280	3,072	135	353.77	271.36	77	19.26	63.15
48	1	2,600	2,380	2,962	124	480.15	263.24	55	19.53	197.38
49	1	3,140	2,020	2,524	125	421.55	225.25	53	18.51	177.79
50	--	--	--	--	--	--	--	--	--	--
51	2	7,060	5,440	6,095	112	1,187.41	541.99	46	40.44	604.98
52	1	3,290	2,690	3,492	130	429.61	308.27	72	22.49	98.85
53	--	--	--	--	--	--	--	--	--	--
54	1	3,280	1,320	2,006	152	494.48	176.90	36	13.30	304.28
55	--	--	--	--	--	--	--	--	--	--
56	1	3,530	2,810	3,189	113	496.42	283.55	57	21.43	191.44
Total	436	498,840	440,260	588,733	134	86,558.90	52,184.28	60	3,683.89	3,069.73

1/ As scaled by the Puget Sound Log Scaling and Grading Bureau in log rafts, Scribner log rule.

2/ Export lumber tally volume as percentage of net scale volume.

3/ Lumber cubic volume as percentage of log cubic volume.

Table 27.—Summary of log scale, Export lumber tally, and cubic volumes by diameter classes—No. 3 logs

Log scaling diameter (inches)	Number of logs	Log scale[1]		Export lumber tally		Cubic volume				
		Gross	Net	Volume	Recovery ratio[2]	Log	Lumber	Lumber recovery ratio[3]	Sawdust	Chippable residue
		Board feet								
6	12	870	870	1,490	171	246.53	133.81	54	10.67	102.05
7	28	1,960	1,930	3,247	168	578.21	291.61	50	24.11	262.49
8	35	3,300	3,170	5,089	161	1,015.84	455.06	45	36.65	524.13
9	40	4,180	3,950	6,800	172	1,186.06	607.74	51	46.95	531.37
10	34	5,600	5,330	8,315	156	1,327.84	739.90	56	54.82	533.12
11	39	6,390	6,200	9,084	147	1,557.81	808.22	52	59.63	689.96
12	54	12,440	12,000	19,505	163	2,980.51	1,729.62	58	119.95	1,130.94
13	52	14,290	13,580	21,064	155	3,310.89	1,870.16	56	131.53	1,309.20
14	24	6,390	5,950	10,411	175	1,470.05	924.39	63	64.24	481.42
15	21	7,230	6,320	9,551	151	1,493.12	847.73	57	58.99	586.40
16	14	5,890	5,080	7,750	153	1,196.71	686.88	57	46.06	463.77
17	13	5,600	4,830	7,707	160	1,091.97	683.19	63	48.19	360.59
18	14	6,430	5,550	9,296	167	1,199.86	824.75	69	56.17	318.94
19	10	4,800	4,080	6,238	153	882.76	553.92	63	38.45	290.39
20	7	3,180	2,040	3,692	181	563.88	329.82	58	24.78	209.28
21	8	6,640	5,750	8,641	150	1,145.02	764.48	67	52.53	328.01
22	7	6,050	4,980	7,779	156	1,029.18	690.65	67	48.56	289.97
23	8	8,500	6,670	10,322	155	1,363.26	919.77	67	67.14	376.35
24	5	6,020	4,980	7,018	141	957.92	624.67	65	44.15	289.10
25	11	10,210	7,810	12,587	161	1,628.66	1,117.62	69	78.61	432.43
26	6	5,570	4,250	6,221	146	852.39	551.76	65	39.98	260.65
27	4	3,980	2,410	4,981	207	625.49	440.87	70	30.55	154.07
28	5	5,830	4,390	9,096	207	893.98	804.73	90	54.71	34.54
29	1	2,010	1,790	1,851	103	300.50	164.03	55	12.36	124.11
30	2	2,950	2,380	3,575	150	495.64	318.14	64	22.72	154.78
31	3	6,160	5,280	6,605	125	998.64	590.13	59	40.67	367.84
32	1	2,430	1,840	2,677	145	347.62	240.51	69	18.39	88.72
33	2	3,230	1,560	1,949	125	440.68	172.84	39	12.44	255.40
34	2	3,200	2,900	4,490	152	504.06	391.16	78	28.38	84.52
35	--	--	--	--	--	--	--	--	--	--
36	1	1,500	580	1,272	219	224.43	112.70	50	7.78	103.95
37	2	4,120	2,490	5,466	220	596.62	485.29	81	35.39	75.94
38	1	2,140	1,930	2,540	132	324.17	226.25	70	16.63	81.29
39	1	2,240	1,230	2,844	231	366.63	252.33	69	18.32	95.98
40	1	1,660	830	1,492	180	227.54	133.03	58	10.73	83.78
41	--	--	--	--	--	--	--	--	--	--
42	--	--	--	--	--	--	--	--	--	--
43	--	--	--	--	--	--	--	--	--	--
44	1	2,410	930	1,824	196	302.72	162.01	54	11.93	128.78
45	--	--	--	--	--	--	--	--	--	--
46	--	--	--	--	--	--	--	--	--	--
47	--	--	--	--	--	--	--	--	--	--
48	1	2,810	2,180	2,683	123	578.50	237.82	41	17.49	323.19
49	2	6,070	5,060	7,378	146	872.42	654.99	75	46.43	171.00
50	--	--	--	--	--	--	--	--	--	--
51	--	--	--	--	--	--	--	--	--	--
52	--	--	--	--	--	--	--	--	--	--
53	--	--	--	--	--	--	--	--	--	--
54	1	3,280	1,380	574	42	425.69	53.14	12	4.70	367.85
Total	473	187,560	154,480	243,023	157	35,603.80	21,595.72	61	1,541.78	12,466.30

[1] As scaled by the Puget Sound Log Scaling and Grading Bureau in log rafts, Scribner log rule.

[2] Export lumber tally volume as percentage of net scale volume.

[3] Lumber cubic volume as percentage of log cubic volume.

Table 28.—Summary of log scale, Export lumber tally, and cubic volumes by diameter classes—all logs

Log scaling diameter (inches)	Number of logs	Log scale[1]		Export lumber tally		Cubic volume				
		Gross	Net	Volume	Recovery ratio[2]	Log	Lumber	Lumber recovery ratio[3]	Sawdust	Chippable residue
		---------- Board feet ----------			Percent	-------- Cubic feet --------		Percent	-------- Cubic feet --------	
6	12	870	870	1,499	171	246.53	133.81	54	10.67	102.05
7	28	1,960	1,930	3,247	168	578.21	291.61	50	24.11	262.49
8	35	3,300	3,170	5,089	161	1,015.84	455.06	45	36.65	524.13
9	40	4,180	3,950	6,800	172	1,186.05	607.74	51	46.95	531.37
10	34	5,600	5,330	8,315	156	1,327.84	739.90	56	54.32	533.12
11	39	6,390	6,200	9,084	147	1,557.81	808.22	52	59.63	689.96
12	54	12,440	12,000	19,505	163	2,980.51	1,729.62	58	119.95	1,130.94
13	52	14,290	13,580	21,064	155	3,310.89	1,870.16	56	131.53	1,309.20
14	41	11,490	10,910	17,847	164	2,570.20	1,585.00	62	109.97	875.23
15	46	16,840	15,700	22,216	142	3,562.24	1,970.58	55	137.94	1,453.72
16	41	17,380	16,210	24,153	149	3,644.64	2,136.74	59	144.95	1,362.95
17	32	14,880	13,780	19,379	141	2,932.45	1,721.25	59	120.80	1,090.40
18	51	27,800	26,040	38,065	146	5,539.57	3,363.42	61	222.83	1,953.32
19	34	21,960	20,370	29,288	144	4,052.89	2,588.76	64	173.36	1,290.77
20	27	19,260	17,520	24,760	141	3,386.68	2,187.37	65	147.33	1,051.98
21	38	32,160	30,460	40,332	132	5,727.37	3,570.12	62	245.34	1,911.91
22	32	27,930	25,670	38,262	149	5,137.21	3,389.75	66	233.97	1,513.49
23	32	29,660	26,470	36,616	138	4,969.18	3,247.15	65	226.39	1,495.64
24	27	30,820	28,840	38,091	133	5,287.93	3,384.35	64	240.34	1,663.24
25	34	38,360	35,010	48,024	137	6,620.24	4,258.65	64	297.56	2,064.03
26	21	24,310	21,060	26,885	128	4,336.61	2,389.22	55	176.47	1,770.92
27	21	26,930	23,700	31,204	132	4,359.77	2,769.40	64	193.41	1,396.96
28	23	34,030	31,040	40,175	129	6,006.83	3,562.85	59	257.97	2,186.01
29	22	31,110	27,980	36,266	130	5,259.24	3,227.44	61	232.50	1,799.30
30	24	36,970	32,000	44,630	139	6,754.01	3,970.03	59	287.57	2,496.41
31	15	25,270	21,880	27,182	124	4,489.82	2,424.47	54	180.06	1,885.29
32	10	16,590	14,890	19,847	133	3,169.27	1,765.50	56	130.97	1,272.80
33	14	26,630	20,920	28,544	136	4,468.13	2,527.64	57	184.86	1,755.63
34	13	22,950	20,680	29,226	141	3,619.45	2,592.28	72	188.27	838.90
35	10	19,980	17,760	23,485	89	3,581.76	2,091.87	58	161.56	1,328.33
36	3	5,310	3,620	5,679	68	829.41	504.08	61	35.85	289.48
37	7	15,070	11,680	18,233	156	2,297.83	1,620.42	71	120.81	556.60
38	12	26,600	21,730	30,013	138	4,134.59	2,663.75	64	194.96	1,275.88
39	7	18,380	15,670	19,529	125	3,538.80	1,733.22	49	127.10	1,678.48
40	11	25,720	19,320	24,556	127	4,310.72	2,181.37	51	160.94	1,968.41
41	5	13,660	11,550	14,768	128	2,631.23	1,310.55	50	95.65	1,207.03
42	10	27,070	20,850	26,842	129	3,877.09	2,390.02	62	179.93	1,307.14
43	3	7,840	6,180	7,347	119	1,033.15	654.09	63	45.26	333.80
44	7	21,720	17,710	22,877	129	3,908.36	2,030.77	52	148.63	1,728.96
45	5	13,130	10,170	13,682	135	1,907.28	1,214.32	64	90.03	602.93
46	7	20,620	14,200	18,378	129	3,007.86	1,643.79	55	125.38	1,238.69
47	3	8,690	7,030	9,304	132	1,326.89	828.03	62	63.85	435.01
48	4	10,610	8,880	11,478	129	1,754.43	1,019.56	58	73.88	660.99
49	7	21,340	17,940	22,826	127	3,656.04	2,027.24	55	149.37	1,479.43
50	1	3,040	2,600	2,740	105	520.42	243.24	47	17.13	260.05
51	3	10,710	8,100	9,702	120	1,882.67	862.70	46	53.89	956.08
52	2	7,090	6,200	7,681	124	1,107.50	680.08	61	50.32	377.10
53	4	14,470	9,770	9,692	99	2,196.22	862.18	39	65.22	1,268.82
54	2	6,560	2,700	2,580	96	920.17	230.04	25	18.00	672.13
55	2	7,370	6,330	7,559	119	1,122.72	671.48	60	50.18	401.06
56	2	7,350	5,970	6,625	111	1,216.68	590.65	49	45.47	580.56
Total	1,009	894,690	774,210	1,051,162	136	158,841.24	93,321.54	59	6,700.58	58,819.12

1/ As scaled by the Puget Sound Log Scaling and Grading Bureau in log rafts, Scribner log rule.

2/ Export lumber tally volume as percentage of net scale volume.

3/ Lumber cubic volume as percentage of log cubic volume.

Table 29.—Export lumber grade yields for Select logs by log scaling diameter

Log scaling diameter (inches)	Number of logs	Total lumber tally	Piano	A	B + C	B and Better[1/]	3 Common[1/]	Select 3 Common[1/]
		Board feet			*percent*			
30	2	3,749	39.37	28.06	31.10	0.91	--	[illegible]
31	--	--	--	--	--	--	--	--
32	2	4,400	35.50	31.02	30.03	2.30	0.50	.66
33	1	3,110	12.35	40.77	41.70	3.38	1.80	--
34	1	1,877	29.62	23.81	39.96	5.70	--	.91
35	4	8,381	41.89	27.62	25.21	3.94	1.05	.29
36	--	--	--	--	--	--	--	--
37	--	--	--	--	--	--	--	--
38	1	2,652	53.02	17.87	24.17	2.26	2.68	--
39	--	--	--	--	--	--	--	--
40	2	3,864	24.84	34.03	36.77	4.35	--	--
41	2	4,730	42.37	29.45	23.45	3.68	1.06	--
42	2	4,524	28.91	28.45	36.47	5.75	.42	--
43	--	--	--	--	--	--	--	--
44	--	--	--	--	--	--	--	--
45	2	5,612	55.81	14.52	25.78	2.39	1.50	--
46	1	3,218	12.49	52.64	27.91	6.15	.81	--
47	1	2,758	35.68	38.29	21.75	3.01	1.27	--
48	1	2,796	1.72	57.08	38.34	2.15	.72	--
49	2	5,710	25.18	40.82	28.77	3.54	1.68	--
50	--	--	--	--	--	--	--	--
51	1	3,607	27.17	53.59	11.75	5.21	2.27	--
52	--	--	--	--	--	--	--	--
53	2	7,353	22.30	53.38	18.39	4.37	1.56	--
54	--	--	--	--	--	--	--	--
55	1	3,582	48.52	24.73	23.45	2.57	.73	--
Total	28	71,923	32.71	34.97	27.45	3.64	1.10	.13

[1/] Local use lumber graded by WCLIB rules.

Table 30.--Export lumber grade yields for No. 1 logs by log scaling diameter

Log scaling diameter (inches)	Number of logs	Total lumber tally	Piano	A	B + C	B and Better[1/]	3 Common[1/]	Below 3 Common[1/]
		Board feet			*Percent*			
24	1	998	8.02	38.78	53.20	--	--	--
25	3	4,593	9.06	38.43	51.44	1.07	--	--
26	3	4,475	7.24	35.51	51.88	3.28	1.74	0.34
27	7	10,845	1.48	52.77	44.51	1.01	.07	.16
28	7	10,872	14.06	31.91	50.29	2.38	.82	.54
29	6	9,242	9.24	44.85	43.94	1.66	.16	.15
30	8	13,504	7.41	48.50	41.04	1.99	.67	.38
31	5	8,094	7.49	50.38	39.57	1.28	.69	.58
32	1	930	--	36.88	57.31	1.94	3.87	--
33	4	8,212	17.34	42.62	39.82	--	.22	--
34	2	3,996	29.20	32.38	35.29	2.93	.20	--
35	1	1,951	23.99	38.49	32.40	5.13	--	--
36	--	--	--	--	--	--	--	--
37	1	1,993	60.21	5.72	30.41	--	3.66	--
38	2	4,966	19.61	27.33	52.34	--	.72	--
39	1	3,555	13.16	60.37	23.94	1.86	.68	--
40	2	3,527	35.38	21.55	36.83	4.56	1.67	--
41	2	7,477	22.55	45.61	29.25	1.71	.88	--
42	3	8,273	40.66	31.90	22.66	2.89	1.89	--
43	--	--	--	--	--	--	--	--
44	1	3,442	26.84	57.35	12.38	2.70	.73	--
45	1	3,383	41.44	27.11	27.73	1.18	2.54	--
46	1	2,709	41.27	27.32	27.57	--	3.84	--
47	1	3,474	35.18	40.18	14.99	6.62	2.53	.49
48	1	3,037	15.01	56.40	28.58	--	--	--
49	2	7,214	29.75	50.15	17.88	.96	1.26	--
50	1	2,740	13.14	45.88	36.53	4.45	--	--
51	--	--	--	--	--	--	--	--
52	1	4,189	19.43	48.34	29.86	2.03	.33	--
53	2	2,339	7.27	27.92	57.16	6.07	1.58	--
54	--	--	--	--	--	--	--	--
55	1	3,977	55.37	23.01	13.86	7.77	--	--
56	1	3,436	9.02	63.42	18.83	5.36	3.20	.17
Total	72	147,443	19.05	41.65	36.05	2.17	.93	.15

[1/] Local use lumber graded by WCLIB rules.

Table 31.—Export lumber grade yields for No. 2 logs by log scaling diameter

Log scaling diameter (inches)	Number of logs	Total lumber tally	Piano	A	B + C	B and Better[1/]	3 Common[1/]	Below 3 Common[1/]
		Board feet	- - -

Table 32.—Export lumber grade yields for No. 3 logs by log scaling diameter

Log scaling diameter (inches)	Number of logs	Total lumber tally	Piano	A	B + C	B and Better[1/]	3 Common[1/]	Below 3 Common[1/]
		Board feet			*Percent*			
6	12	1,490	--	--	99.53	0.47	--	--
7	28	3,247	--	11.24	87.68	.40	0.68	--
8	35	5,089	--	6.33	92.67	.83	--	0.18
9	40	6,800	--	5.20	93.90	.39	.19	.34
10	34	8,315	--	16.57	82.08	.71	.34	.30
11	39	9,084	--	20.50	78.97	.54	--	--
12	54	19,505	--	32.37	67.33	.26	.04	--
13	52	21,064	--	29.25	69.70	.67	.28	.10
14	24	10,411	--	20.65	78.99	--	.07	.29
15	21	9,551	--	22.45	76.06	.76	.55	.17
16	14	7,750	--	24.39	75.43	--	.09	.09
17	13	7,707	--	23.03	76.28	--	.38	.31
18	14	9,296	--	27.31	72.22	.08	.39	--
19	10	6,238	1.15	26.45	71.66	.51	.10	.13
20	7	3,692	--	7.04	92.04	.27	.57	.08
21	8	8,641	--	49.97	49.90	.13	--	--
22	7	7,779	3.19	32.29	63.66	.55	.10	.21
23	8	10,322	2.02	18.89	77.26	1.00	.83	--
24	5	7,018	--	33.41	65.26	1.03	.23	.07
25	11	12,587	--	34.76	63.60	1.03	.24	.37
26	6	6,221	1.67	41.81	55.60	.63	--	.29
27	4	4,981	1.93	52.50	45.57	--	--	--
28	5	9,096	--	71.32	28.41	--	.24	.03
29	1	1,851	--	48.35	50.68	.97	--	--
30	2	3,575	3.24	54.29	42.18	.28	--	--
31	3	6,605	1.85	11.84	85.37	.53	.41	--
32	1	2,677	2.47	40.42	54.13	1.01	1.98	--
33	2	1,949	--	47.61	52.38	--	--	--
34	2	4,409	3.49	57.20	38.10	--	.73	.48
35	--	--	--	--	--	--	--	--
36	1	1,272	--	7.08	92.92	--	--	--
37	2	5,466	1.10	35.42	63.49	--	--	--
38	1	2,540	2.36	27.32	70.32	--	--	--
39	1	2,844	17.23	56.75	26.02	--	--	--
40	1	1,492	--	38.54	56.57	3.69	--	1.21
41	--	--	--	--	--	--	--	--
42	--	--	--	--	--	--	--	--
43	--	--	--	--	--	--	--	--
44	1	1,824	--	30.65	69.35	--	--	--
45	--	--	--	--	--	--	--	--
46	--	--	--	--	--	--	--	--
47	--	--	--	--	--	--	--	--
48	1	2,683	38.84	27.25	29.37	4.55	--	--
49	2	7,378	10.08	49.31	38.03	1.76	.81	--
50	--	--	--	--	--	--	--	--
51	--	--	--	--	--	--	--	--
52	--	--	--	--	--	--	--	--
53	--	--	--	--	--	--	--	--
54	1	574	--	--	96.52	--	1.74	1.74
Total	473	243,023	1.47	30.60	67.01	.54	.26	.12

[1/] Local use lumber graded by WCLIB rules.

Table 33.—Export lumber grade yields for all grade logs by log scaling diameter

Log scaling diameter (inches)	Number of logs	Total lumber tally	Piano	A	B + C	B and Better[1/]	3 Common[1/]	Below 3 Common[1/]
		Board feet	- - -

Table 34.—The distribution of study lumber by Export grade, thickness, and width for Select logs

Thickness	Width	Piano	A	B + C	B and Better[1]	3 Common[1]	Below 3 Common[1]	Lumber volume	
								Percent	Board feet
Inches		*Percent*							
1	2	--	--	--	--	--	100.0	[2]	3
	4	--	--	--	--	4.3	95.7	0.1	92
	6	--	--	--	10.8	89.2	--	.3	204
	8	--	--	--	100.0	--	--	.1	55
2	4	--	--	--	78.7	21.3	--	.1	361
	6	--	--	--	79.7	20.3	--	2.1	1,498
	7	--	--	--	100.0	--	--	[2]	14
	8	--	--	--	80.0	20.0	--	.6	480
	10	--	--	--	67.5	32.5	--	.2	163
	12	--	--	--	88.5	11.5	--	.9	628
3	3	--	--	100.0	--	--	--	[2]	21
	4	--	21.0	79.0	--	--	--	.1	95
	5	--	--	100.0	--	--	--	[2]	17
	6	--	3.5	96.5	--	--	--	.7	513
	8	--	--	100.0	--	--	--	[2]	28
4	4	--	41.7	58.3	--	--	--	.4	307
	5	--	--	100.0	--	--	--	.4	267
	6	22.5	18.6	68.9	--	--	--	4.0	2,880
	7	--	--	100.0	--	--	--	[2]	28
	8	45.2	27.4	27.4	--	--	--	.2	117
	12	100.0	--	--	--	--	--	.2	160
5	5	--	--	100.0	--	--	--	.1	42
	6	--	16.9	83.1	--	--	--	1.7	1,240
6	6	37.5	37.3	25.2	--	--	--	13.8	9,900
	7	--	70.3	29.7	--	--	--	4.5	3,239
	8	38.0	34.2	27.8	--	--	--	21.6	15,448
	9	--	68.8	31.2	--	--	--	3.6	2,575
	10	41.2	37.6	21.2	--	--	--	17.0	12,190
	11	--	57.8	42.2	--	--	--	4.9	3,542
	12	51.2	31.5	17.3	--	--	--	12.9	9,228
	13	--	--	100.0	--	--	--	.6	403
	14	54.0	31.3	14.7	--	--	--	5.2	3,710
	15	--	100.0	--	--	--	--	.5	390
	16	89.8	10.2	--	--	--	--	1.3	944
	18	66.7	33.3	--	--	--	--	.4	324
	20	59.1	40.9	--	--	--	--	.6	440
9	9	--	--	100.0	--	--	--	.5	377
		Board feet							
Total		23,529	25,152	19,744	2,617	790	91		71,923

[1] Local lumber use graded by WCLIB rules.

[2] Percentage is less than 0.05.

Table 35.—The distribution of study lumber by Export grade, thickness, and width for No. 1 logs

Thickness	Width	Piano	A	B + C	1 and Better 1/	3 Common 1/	Below 3 Common	Lumber volume	
								Percent	Board feet
Inches		Percent							
1	4	--	--	--	10.9	14.7	74.4	0.2	2,265
	6	--	--	--	4.3	93.4	2.3	.4	601
	8	--	--	--	91.0	9.0	--	.1	144
	12	--	--	--	--	44.4	55.6	.2	287
2	4	--	--	--	86.8	13.2	--	.4	4,586
	5	--	--	--	--	100.0	--	2/	10
	6	--	--	--	75.2	24.8	--	1.0	1,467
	8	--	--	--	81.2	18.8	--	.5	752
	10	--	--	--	85.5	14.5	--	.3	413
	12	--	--	--	80.9	19.1	--	.3	440
	14	--	--	--	100.0	--	--	2/	15
3	3	--	--	100.0	--	--	--	2/	31
	4	--	--	100.0	--	--	--	.1	52
	5	--	--	100.0	--	--	--	2/	17
	6	10.8	--	89.2	--	--	--	.8	1,116
	7	--	--	100.0	--	--	--	2/	35
	8	--	--	100.0	--	--	--	2/	28
4	4	2.6	36.6	60.8	--	--	--	0.7	1,019
	5	--	--	100.0	--	--	--	0.3	433
	6	28.2	7.1	64.7	--	--	--	3.4	5,088
	7	--	34.0	66.0	--	--	--	.1	219
	8	28.3	14.8	56.9	--	--	--	.2	357
	10	73.9	--	26.1	--	--	--	.1	180
	12	78.6	21.4	--	--	--	--	.3	448
	14	62.2	--	37.8	--	--	--	.2	296
	16	100.0	--	--	--	--	--	.1	128
5	5	--	--	100.0	--	--	--	2/	67
	6	--	.7	99.3	--	--	--	1.9	2,875
	7	--	100.0	--	--	--	--	2/	58
	12	--	100.0	--	--	--	--	2/	70
6	6	23.3	47.7	29.0	--	--	--	9.1	13,428
	7	--	65.1	34.9	--	--	--	5.7	8,358
	8	17.1	42.6	40.3	--	--	--	23.3	34,128
	9	--	53.6	46.4	--	--	--	7.0	10,314
	10	22.2	40.5	37.3	--	--	--	17.8	25,890
	11	--	73.2	26.8	--	--	--	5.0	7,338
	12	34.2	42.6	23.2	--	--	--	9.9	14,604
	13	--	60.8	39.2	--	--	--	1.4	2,054
	14	51.1	34.3	14.6	--	--	--	4.8	7,128
	15	--	100.0	--	--	--	--	.5	750
	16	43.5	42.4	14.1	--	--	--	.9	360
	17	--	100.0	--	--	--	--	.2	255
	18	70.1	18.4	11.5	--	--	--	1.1	1,566
	20	100.0	--	--	--	--	--	.6	413
9	10	33.4	--	66.6	--	--	--	.4	630
10	10	--	--	100.0	--	--	--	.8	1,167
	12	--	100.0	--	--	--	--	.1	220
				Board feet					
Total		28,093	61,407	53,155	3,194	1,368	226	100.0	147,443

1/ Local lumber use graded by WCLIB rules.
2/ Percentage is less than 0.05.

Table 36.—The distribution of study lumber by Export grade, thickness, and width for No. 2 logs

Thickness	Width	Prime	A	B + C	B and Better[1]	3 Common[1]	Below 3 Common[1]	Lumber volume	
								Percent	Board feet
Inches									
1	4	--	--	--	1.9	17.8	80.3	0.1	376
	6	--	--	--	5.5	89.3	5.2	.1	685
	8	--	--	--	90.9	--	9.1	2/	88
	12	--	--	--	--	100.0	--	2/	26
2	3	--	--	--	100.0	--	--	2/	10
	4	--	--	--	54.8	43.5	1.7	.2	1,333
	5	--	--	--	100.0	--	--	2/	15
	6	--	--	--	68.8	30.9	.3	.4	2,706
	8	--	--	--	73.1	25.7	1.2	.2	1,277
	10	--	--	--	48.7	51.3	--	2/	273
	12	--	--	--	58.9	41.1	--	.1	672
3	4	--	--	100.0	--	--	--	2/	74
	5	--	--	100.0	--	--	--	2/	40
	6	1.5	4.9	93.6	--	--	--	.5	2,850
	8	--	23.4	76.6	--	--	--	2/	188
	10	--	--	100.0	--	--	--	2/	60
	12	52.0	--	48.0	--	--	--	2/	150
	16	--	100.0	--	--	--	--	2/	48
4	4	--	32.5	67.5	--	--	--	.3	1,632
	5	--	--	100.0	--	--	--	.2	1,171
	6	8.1	11.1	80.8	--	--	--	1.8	10,308
	7	--	35.4	64.6	--	--	--	.2	1,461
	8	--	19.7	80.3	--	--	--	.2	1,515
	9	--	22.9	77.1	--	--	--	.1	498
	10	--	54.4	45.6	--	--	--	2/	294
	11	--	19.6	80.4	--	--	--	.1	337
	12	21.4	57.2	21.4	--	--	--	.1	448
	13	--	30.0	70.0	--	--	--	.1	347
	14	--	28.9	71.1	--	--	--	.1	485
	15	--	40.0	60.0	--	--	--	2/	150
5	5	--	--	100.0	--	--	--	2/	58
	6	--	4.4	95.6	--	--	--	1.4	8,365
	7	--	100.0	--	--	--	--	2/	70
	8	--	50.0	50.0	--	--	--	2/	120
	14	--	100.0	--	--	--	--	2/	117
6	6	13.7	45.9	40.4	--	--	--	7.8	45,636
	7	--	52.5	47.5	--	--	--	6.0	35,560
	8	11.2	42.4	46.4	--	--	--	24.1	140,613
	9	--	55.1	44.9	--	--	--	7.6	44,595
	10	6.1	47.1	46.8	--	--	--	19.4	113,850
	11	--	66.4	33.6	--	--	--	4.3	25,256
	12	20.1	57.8	22.1	--	--	--	7.1	42,060
	13	--	74.9	25.1	--	--	--	2.7	15,938
	14	15.5	62.2	22.3	--	--	--	4.3	25,326
	15	--	84.4	15.6	--	--	--	2.1	12,285
	16	9.6	80.6	9.8	--	--	--	2.6	15,408
	17	--	79.0	21.0	--	--	--	2.3	13,736
	18	3.9	85.5	10.6	--	--	--	1.9	11,016
	19	--	61.2	38.8	--	--	--	.6	3,382
	20	--	44.4	55.6	--	--	--	.4	2,340
7	9	--	--	100.0	--	--	--	2/	210
8	8	--	100.0	--	--	--	--	2/	128
	9	--	100.0	--	--	--	--	2/	132
9	9	--	--	100.0	--	--	--	.2	945
	10	--	--	100.0	--	--	--	2/	420
10	10	--	--	100.0	--	--	--	.2	1,050
	12	--	--	100.0	--	--	--	.1	640
					Board feet				
Total		44,444	296,610	240,257	4,205	2,864	393	100.0	588,773

1/ Local use lumber graded by WCLIB rules.

2/ Percentage is less than 0.05.

Table 37.—The distribution of study lumber by Export grade, thickness, and width for No. 3 logs

Thickness	Width	Piano	A	B + C	B and Better[1]	3 Common[1]	[illegible] Common[1]	Lumber volume	
								Percent	Board feet
1	4	--	--	--	3.2	13.8	83.0	0.1	282
	6	--	--	--	--	100.0	--	2/	41
	8	--	--	--	63.6	--	36.4	2/	33
2	4	--	--	--	64.0	30.4	5.6	.2	59[illegible]
	6	--	--	--	58.8	36.9	4.3	.2	602
	8	--	--	--	69.6	30.4	--	.2	438
	10	--	--	--	100.0	--	--	2/	33
	12	--	--	--	92.7	7.3	--	.1	220
3	4	--	--	100.0	--	--	--	2/	68
	5	--	--	100.0	--	--	--	2/	70
	6	--	--	100.0	--	--	--	.6	1,479
	8	--	--	100.0	--	--	--	2/	40
	10	--	--	100.0	--	--	--	2/	30
4	4	--	37.6	62.4	--	--	--	.3	752
	5	--	--	100.0	--	--	--	.5	1,126
	6	1.9	6.4	91.7	--	--	--	2.2	5,384
	7	--	12.6	87.4	--	--	--	.5	1,334
	8	--	4.2	95.8	--	--	--	.6	1,520
	9	--	7.2	92.8	--	--	--	.2	498
	10	--	4.8	95.2	--	--	--	.3	827
	11	--	45.7	54.3	--	--	--	.1	257
	12	--	--	100.0	--	--	--	.1	272
	13	--	--	100.0	--	--	--	2/	104
	14	--	--	100.0	--	--	--	.1	261
5	5	--	--	100.0	--	--	--	2/	25
	6	--	1.2	98.8	--	--	--	1.5	3,750
	7	--	--	100.0	--	--	--	2/	70
	8	--	--	100.0	--	--	--	2/	40
	9	--	--	100.0	--	--	--	2/	90
	11	--	--	100.0	--	--	--	2/	110
	12	--	--	100.0	--	--	--	2/	120
6	6	2.6	27.9	69.5	--	--	--	6.6	16,128
	7	--	23.7	76.3	--	--	--	9.9	23,996
	8	2.6	25.8	71.6	--	--	--	20.7	49,672
	9	--	28.8	71.2	--	--	--	11.3	27,333
	10	1.7	25.2	73.1	--	--	--	18.0	43,100
	11	--	44.4	55.6	--	--	--	6.6	15,939
	12	4.1	47.8	48.1	--	--	--	5.7	13,788
	13	---	52.0	48.0	--	--	--	3.7	8,840
	14	--	62.0	38.0	--	--	--	3.2	7,756
	15	--	67.7	32.3	--	--	--	1.5	3,615
	16	5.8	61.6	32.6	--	--	--	2.1	5,200
	17	--	88.0	12.0	--	--	--	.7	1,700
	18	--	51.3	48.7	--	--	--	.6	1,404
	19	--	34.3	65.7	--	--	--	.5	1,330
	20	24.1	--	75.9	--	--	--	.2	580
8	8	--	--	100.0	--	--	--	.2	373
	10	--	--	100.0	--	--	--	.1	187
	11	--	--	100.0	--	--	--	2/	117
9	9	--	--	100.0	--	--	--	.2	472
	10	--	--	100.0	--	--	--	.1	210
10	10	--	--	100.0	--	--	--	.3	817
				- Board feet					
	Total	3,582	74,353	162,847	1,305	632	304	100.0	243,023

1/ Local use lumber graded by WCLIB rules.

2/ Percentage is less than 0.05.

Table 38.—The distribution of study lumber by Export grade, thickness, and width for all log grades

Thickness	Width	Prime	A	B + C	B and Better[1]	3 Common[1]	Below 3 Common[1]	Lumber volume	
								Percent	Board feet
Inches									
1	2	--	--	--	--	--	100.0	[2]	3
	4	--	--	--	4.4	14.7	80.9	0.1	1,015
	6	--	--	--	5.6	91.1	3.3	.1	1,531
	8	--	--	--	90.0	4.1	5.9	[2]	320
	12	--	--	--	--	71.7	28.3	[2]	53
2	3	--	--	--	100.0	--	--	[2]	10
	4	--	--	--	66.6	31.5	1.9	.3	2,923
	5	--	--	--	60.0	40.0	--	[2]	25
	6	--	--	--	72.0	27.5	.5	.6	6,273
	7	--	--	--	100.0	--	--	[2]	14
	8	--	--	--	75.8	23.7	.5	.3	2,947
	10	--	--	--	71.3	28.7	--	.1	882
	12	--	--	--	77.2	22.8	--	.2	1,960
	14	--	--	-	100.0	--	--	[2]	33
3	3	--	--	100.0	--	--	--	[2]	52
	4	--	6.3	93.7	--	--	--	[2]	317
	5	--	--	100.0	--	--	--	[2]	144
	6	3.7	2.7	94.6	--	--	--	.6	5,958
	7	--	--	100.0	--	--	--	[2]	35
	8	--	15.5	84.5	--	--	--	[2]	284
	10	--	--	100.0	--	--	--	[2]	90
	12	52.0	--	48.0	--	--	--	[2]	150
	16	--	100.0	--	--	--	--	[2]	48
4	4	.7	35.4	63.9	--	--	--	.4	3,711
	5	--	--	100.0	--	--	--	.3	2,997
	6	12.8	8.8	78.4	--	--	--	2.2	23,660
	7	--	25.0	75.0	--	--	--	.3	3,042
	8	4.4	12.8	82.8	--	--	--	.3	3,509
	9	--	15.1	84.9	--	--	--	.1	996
	10	10.2	15.4	74.4	--	--	--	.1	1,300
	11	--	30.9	69.1	--	--	--	.1	593
	12	45.8	26.5	27.7	--	--	--	.1	1,328
	13	--	23.0	77.0	--	--	--	[2]	451
	14	17.6	13.4	69.0	--	--	--	.1	1,042
	15	--	40.0	60.0	--	--	--	[2]	150
	16	100.0	--	--	--	--	--	[2]	128
5	5	--	--	100.0	--	--	--	[2]	192
	6	--	4.0	96.0	--	--	--	1.5	16,230
	7	--	64.6	35.4	--	--	--	[2]	198
	8	--	37.5	62.5	--	--	--	[2]	160
	9	--	--	100.0	--	--	--	[2]	90
	11	--	--	100.0	--	--	--	[2]	110
	12	--	100.0	--	--	--	--	[2]	190
	14	--	100.0	-	--	--	--	[2]	117
6	6	15.9	41.8	42.3	--	--	--	8.1	85,092
	7	--	45.1	54.9	--	--	--	6.8	71,153
	8	12.0	38.4	49.6	--	--	--	22.9	239,861
	9	--	46.8	53.2	--	--	--	8.1	84,818
	10	9.5	40.7	49.8	--	--	--	18.7	195,030
	11	--	60.1	39.9	--	--	--	5.0	52,075
	12	23.5	50.3	26.2	--	--	--	7.6	79,680
	13	--	65.8	34.2	--	--	--	2.6	27,638
	14	21.8	55.0	23.2	--	--	--	4.2	43,920
	15	--	81.9	18.1	--	--	--	1.6	17,040
	16	14.0	71.3	14.7	--	--	--	2.2	23,046
	17	--	80.3	19.7	--	--	--	1.5	15,691
	18	12.2	73.6	14.2	--	--	--	1.4	14,310
	19	--	53.6	46.4	--	--	--	.4	4,712
	20	20.8	32.6	46.6	--	--	--	.4	3,740
7	9	--	--	100.0	--	--	--	[2]	210
8	8	--	25.5	74.5	--	--	--	[2]	501
	9	--	100.0	--	--	--	--	[2]	132
	10	--	--	100.0	--	--	--	[2]	187
	11	--	--	100.0	--	--	--	[2]	117
9	9	--	--	100.0	--	--	--	.2	1,794
	10	22.2	--	77.8	--	--	--	.1	1,260
10	10	--	--	100.0	--	--	--	.3	3,034
	12	--	25.6	74.4	--	--	--	.1	860
				Board feet					
Total		99,648	457,522	476,003	11,321	5,654	1,014	100.0	1,051,162

[1] Local use lumber graded by WCLIB rules.
[2] Percentage is less than 0.05.

Table 39.—The distribution of study lumber by Export grade and length for Select logs

Board length (feet)	Piano	A	B + C	B and Better[1/]	3 Common[1/]	Below 3 Common[1/]	Lumber volume	
							Percent	Board feet
				Percent				
8	3.6	8.9	7.1	67.0	13.4	--	0.6	[illegible]
10	21.5	17.8	11.6	36.4	12.7	--	.8	605
12	39.7	33.2	22.1	2.7	2.3	--	22.1	15,825
14	40.6	28.6	24.2	4.9	1.5	0.2	17.3	12,471
16	18.1	25.2	25.7	26.3	2.4	2.3	1.8	1,324
18	36.6	29.5	29.4	4.0	.3	--	14.5	10,434
20	32.8	35.6	29.9	1.4	.1	.2	15.7	11,253
22	35.3	17.7	26.5	20.5	--	--	.3	249
24	11.4	49.7	38.1	.8	--	--	15.6	11,144
26	35.9	39.0	25.1	--	--	--	11.3	8,169
				Board feet				
Total	23,529	25,152	19,744	2,617	790	91	100.0	71,923

1/ Local use lumber graded by WCLIB rules.

Table 40.—The distribution of study lumber by Export grade and length for No. 1 logs

Board length (feet)	Piano	A	B + C	B and Better[1/]	3 Common[1/]	Below 3 Common[1/]	Lumber volume	
							Percent	Board feet
				Percent				
6	--	--	--	100.0	--	--	2/	4
8	10.0	13.6	33.2	33.4	8.6	1.2	0.4	638
10	--	15.4	29.2	33.9	19.5	2.0	.4	650
11	--	--	--	--	100.0	--	--	[illegible]
12	25.7	38.5	30.7	3.2	1.6	.3	17.8	26,204
14	37.3	29.7	29.7	2.4	.8	.1	15.1	22,207
16	2.5	22.9	30.6	36.7	5.2	2.1	.9	1,292
18	15.1	45.4	37.0	1.3	1.1	.1	13.9	20,476
20	12.0	45.5	40.9	1.0	.5	.1	33.8	49,879
22	12.3	53.2	30.2	3.8	.5	--	1.6	2,332
24	12.8	46.9	39.6	.5	.2	--	9.1	13,468
26	18.7	45.8	35.5	--	--	--	7.0	10,287
				Board feet				
Total	28,093	61,407	53,135	3,194	1,368	226	100.0	53,135

1/ Local use lumber graded by WCLIB rules.
2/ Percentage is less than 0.05.

Table 41.—The distribution of study lumber by Export grade and length for No. 2 logs

Board length (feet)	Prime	A	B + C	B and Better[1]	3 Common[1]	Below 3 Common[1]	Lumber volume	
							Percent	Board feet
6	--	--	83.3	--	16.7	--	2/	36
8	--	14.4	85.9	99.3	11.8	2.9	0.2	1,276
10	2.1	27.4	68.6	21.9	9.8	2.1	.3	1,870
12	18.2	42.8	36.2	1.3	1.3	.2	10.8	63,464
14	12.1	40.0	46.4	1.5	1.0	.1	8.2	48,395
16	7.4	32.2	40.4	16.3	5.7	.8	.7	4,091
18	7.2	43.6	47.9	.7	.6	.1	11.7	68,808
20	5.7	47.4	35.1	.4	.4	--	34.4	202,309
21	100.0	--	--	--	--	--	2/	84
22	1.8	39.6	57.4	.7	.5	--	1.8	10,802
24	7.1	53.9	40.6	.2	.2	2/	25.0	147,170
26	6.5	48.1	45.4	--	-	--	6.8	40,148
32	--	--	100.0	--	-	--	.1	320
Total	44,444	290,615	248,257	4,205	2,864	393	100.0	588,773

1/ Local use lumber graded by WCLIB rules.
2/ Percentage is less than 0.05.

Table 42.—The distribution of study lumber by Export grade and length for No. 3 logs

Board length (feet)	Prime	A	B + C	B and Better[1]	3 Common[1]	Below 3 Common[1]	Lumber volume	
							Percent	Board feet
8	—	11.3	45.0	26.4	13.5	3.8	0.2	497
10	--	16.3	34.4	27.5	15.3	6.5	.2	523
11	--	--	--	--	--	100.0	2/	4
12	1.3	27.5	65.9	.9	.5	.2	10.7	26,056
14	4.2	20.5	74.8	1.0	.4	.1	8.9	21,650
16	3.6	3.8	79.6	7.9	2.9	2.2	.9	2,223
18	1.6	6.4	68.0	.5	.3	.2	13.5	32,817
20	.6	35.4	63.6	.2	.1	.1	32.4	78,725
22	.9	22.3	75.7	.2	.3	--	3.1	7,257
24	.3	28.3	71.3	.1	.2	--	22.5	54,738
26	1.7	41.6	55.6	--	.1	--	7.6	18,533
Total	3,582	74,353	162,847	1,305	632	304	100.0	243,023

1/ Local use lumber graded by WCLIB rules.
2/ Percentage is less than 0.05.

Table 43.—The distribution of study lumber by Export grade and length for all logs

Board length (feet)	Prime	A	B + C	B and Better[1]	3 Common[1]	Below 3 Common[1]	Lumber volume	
							Percent	Board feet
6	-	--	75.0	10.0	15.0	--	2/	40
8	2.8	15.1	81.9	37.3	11.6	2.2	0.3	2,860
10	4.7	22.1	30.8	27.1	12.8	2.4	.3	3,648
11	--	--	--	--	60.0	40.0	2/	10
12	19.6	37.7	39.4	1.8	1.3	.2	12.5	131,548
14	19.0	32.4	45.6	2.0	.9	.1	10.0	104,723
16	7.7	22.8	47.0	18.6	4.4	1.5	.8	8,930
18	9.3	39.2	49.9	.9	.6	.1	12.6	132,535
20	6.3	49.0	44.2	.3	.2	--	32.6	342,167
21	100.0	--	--	--	--	--	2/	84
22	3.1	45.2	50.0	1.3	.4	--	2.0	20,640
24	4.7	47.1	47.9	.2	.1	--	21.6	226,520
26	10.1	45.5	44.4	--	--	--	7.3	77,137
32	--	-	100.0	--	--	--	2/	320
Total	99,648	474,532	476,008	11,322	5,654	1,014	100.0	1,051,162

1/ Local use lumber graded by WCLIB rules.
2/ Percentage is less than 0.05.

☆ GPO—796-096

Lane, Paul H., Richard O. Woodfin, Jr., John W. Henley, and Marlin E. Plank

1972. Lumber yield from Sitka spruce in southeastern Alaska. USDA Forest Serv. Res. Pap. PNW-134, 44 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

About 98 percent of the Sitka spruce lumber sawn in a southeastern Alaska lumber recovery study was in cants 3 to 8 inches in thickness. Thirteen percent of the lumber volume was graded No. 2 and 3 Clear by the Pacific Lumber Inspection Bureau rules and 9 percent Piano under Export rules.

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GERMINATION AND EARLY GROWTH OF COASTAL TREE SPECIES ON ORGANIC SEED BEDS

DON MINORE

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u.s. department of agriculture forest service

ABSTRACT

Germination and early growth on rotten wood and duff under several shade levels were observed for Douglas-fir, Sitka spruce, western hemlock, western redcedar, lodgepole pine, Pacific silver fir, and red alder. Nutrients were more abundant in duff than in rotten wood. Seedlings usually were larger and more abundant on duff-covered rotten logs than on duff-covered mineral soil under dense coastal stands. Duff accumulations were thicker on logs and over rotten wood embedded in the soil than over mineral soil alone. Shade limited root growth more than height growth, and seed bed differences limited height growth more than root growth. All conifer species responded similarly to the seed bed and shade differences tested, and type of organic seed bed probably does not affect species composition of forest regeneration under lightly thinned shelterwoods in coastal Oregon. Preserving duff accumulations under shaded conditions benefits early growth of all conifer species.

Keywords: Seed germination, growth factors.

INTRODUCTION

Shelterwood cutting is increasing in coastal forests, largely because it preserves scenic values better than clearcutting. It also creates regeneration conditions quite different from those created by clearcutting--there is less light, less exposed mineral soil, and more organic seed bed material. Most of the forest floor remains covered with accumulations of duff and rotten wood after shelterwood cutting. These accumulations vary in distribution, depth, and state of decay. They are not always equally suitable seed beds. Seeds and seedlings of coastal tree species vary in physiological characteristics and requirements, and each may respond differently to different seed beds. Knowledge of seed bed-species relationships is needed to facilitate seedling establishment and growth and to control species composition under shelterwood canopies.

Germination and early growth on organic seed beds have been studied in several regions. In eastern Canada, balsam fir (*Abies balsamea* (L.) Mill.) and white spruce (*Picea glauca* (Moench) Voss) seedlings often grow on rotten logs and stumps but not on surrounding duff (Place 1955). However, undisturbed duff is a better seed bed than mineral soil for Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) on central Montana clearcuts (Hatch and Lotan 1969). MacBean (1941) found that duff supported 40 percent of the western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) seedlings on a logged area on Vancouver Island. When adequate moisture is supplied, hemlock seedlings grow taller on duff than on either rotten wood or mineral soil in British Columbia (Sutton 1954). Western hemlock reproduction is better than that of red alder (*Alnus rubra* Bong.), Sitka spruce (*Picea sitchensis* (Bong.) (Carr.), or western redcedar (*Thuja plicata* Donn) on organic seed beds in coastal British Columbia (Day 1957). It is also better than Sitka spruce reproduction on the organic seed beds of southeastern Alaska (Taylor 1935). Other organic seed bed-species relationships and rotten wood-duff differences are less evident. However, small-seeded species are less successful than large-seeded ones on exposed duff seed beds (Haig, Davis, and Weidman 1941), and shade benefits the germination and survival of most species on most seed beds in British Columbia (Garman 1955).

In the three studies presented here, organic seed beds and coastal Oregon tree species were compared to determine seed bed-species relationships.

FIELD OBSERVATIONS

General observations in coastal Oregon forests indicated that seed bed relationships are influenced by shade. In heavy shade (less than 10 percent full sunlight as measured by a Weston Model 756 illumination meter[1/]), most coastal

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[1/] Mention of a product does not imply endorsement by the U.S. Department of Agriculture.

Oregon conifer seedlings occur on rotten logs, not on the duff-covered forest floor. Rotten logs also are better seed beds than forest-floor duff in moderate shade (10 to 40 percent full sunlight). Both rotten logs and forest-floor duff are excellent seed beds in light shade (40 to 60 percent full sunlight). Both are unsatisfactory seed beds in full sunlight.

Paired plot observations were used to compare the occurrence and heights of native Sitka spruce and western hemlock seedlings on rotten log and forest floor seed beds in moderate shade. These plots were established in stands less than 6 kilometers from the ocean at Cascade Head Experimental Forest near Otis, Oregon. A rotten log comprised one rectangular plot in each pair. A second plot was established by marking off an equal area on the forest floor 1.2 meters away. A coin flip determined offset direction perpendicular to the long axis of the log. The two plots in each pair were of equal size and shape, but sizes and shapes differed among pairs as log sizes and shapes differed. All spruce and hemlock seedlings less than 2 meters tall were counted on each plot, heights of the tallest seedlings of each species on each plot were measured, and the area of each plot was calculated. The resulting height and density data were subjected to analyses of variance. Both species were taller and more numerous on rotten logs than on the forest floor (table 1).

Table 1.--*Average seedling density and heights of tallest seedlings on moderately shaded seed beds, by seed bed type and species*

Seed bed	Average number of seedlings per square meter[1/]		Average height of tallest seedling[2/]	
	Spruce	Hemlock	Spruce	Hemlock
			- - - *Centimeters* - - -	
Rotten logs	16.8	52.1	44.7	55.1
Adjacent forest floor	10.3	23.0	24.9	43.9

[1/] Density differences for both seed beds and species are highly significant ($p = 0.99$).

[2/] Height differences for seed beds are significant ($p = 0.95$) and for species, highly significant.

Thornburgh,[2/] working in the Cascade Mountains of Washington, noted that small hemlock seedlings reach maturity only on those rotten logs which have a solid, undecayed core surrounded by a thin shell of rotten wood. This limitation of seedling maturation to a specific log condition was not observed

[2/] Dale A. Thornburgh. Dynamics of the true fir-hemlock forests of the west slope of the Washington Cascade Range. 210 p., 1969. (Unpubl. Ph. D. thesis on file at Univ. Wash., Seattle.)

in coastal Oregon. Both seedling and mature hemlock and Sitka spruce trees were found on logs with both solid cores and cores in several stages of decay (fig. 1).

Figure 1.—Three hemlocks growing on a completely rotten log. The smallest seedling at left (roots exposed) is 18 years old and 2 meters tall. The middle tree is 8-centimeters d.b.h., and the large tree at right is 60-centimeters d.b.h.

Logs on which seedlings were growing were compared with the surrounding forest floor to determine why the logs made better seed beds in moderate and heavy shade than the forest floor. Apparently moisture differences between forest floor duff and rotten wood were not responsible. Although rotten wood retained more moisture than duff, both remained moist throughout the summer in the heavily shaded areas where seed bed differences were most evident. Nor did log elevation above the surrounding forest floor seem to be responsible for the log-forest floor difference. Occasional hemlock seedlings were found growing on the level forest floor in heavy shade but only over buried pieces of rotten wood (fig. 2). The forest floor duff seemed thicker over these buried pieces of rotten wood than over the adjacent mineral soil. Reexamination of the rotten logs showed that those logs supporting seedlings also had thick duff accumulations. Accordingly, paired measurements of duff thickness on rotten wood and mineral soil were made in 50 shaded areas. The duff varied greatly, but accumulations were significantly thicker over buried pieces of rotten wood and on the tops of rotten logs where seedlings occurred than they were over mineral soil. Duff apparently decomposes more slowly over rotten wood than it does over mineral soil.

Figure 2.—Uprooted hemlock seedling with roots embedded in buried rotten wood.

LABORATORY EXPERIMENTS

Methods

To test organic seed beds under controlled conditions, rotten Douglas-fir wood and hemlock duff were collected on the Cascade Head Experimental Forest. Each material was air-dried, screened through 8-millimeter mesh, blended to insure uniformity, and chemically analyzed. Clay pots were filled with weighed quantities of the seed bed materials, then immersed in water to the pot collars. After both rotten wood and duff seed beds were saturated, equal numbers of seeds (all of the same species) were placed on the seed bed surface in each pot (fig. 3). Douglas-fir, Sitka spruce, lodgepole pine, western hemlock, western redcedar, Pacific silver fir, and red alder seeds from low-elevation coast sources were used. Each seed bed-species combination was replicated five times. All pots were covered with polyethylene to prevent drying of seeds. They were then placed in a growth chamber set for 16-hour, 20° C. days and 8-hour, 8° C. nights. A combination of incandescent, cool white, and warm white fluorescent lamps provided 1,500 foot-candles of light at the seed bed surfaces.

Figure 3.—Seed beds in the growth chamber. Polyethylene pot covers kept the seeds moist, and the pots were watered from below by filling the lower containers.

Seed beds were kept moist by watering from below until germination was complete and then watered regularly from above. Germinating seeds were counted every 3 days, and the total numbers of germinating seeds in each seed bed were compared by analyses of variance. Germination rates, as determined by the number of days required for germination to be 50 percent complete in each pot, were also compared by analyses of variance.

The seedlings were grown for 16 weeks in the growth chamber, then harvested, ovendried, and weighed. Seedling survival, based on the number of germinating seeds, was compared among seed beds by analysis of variance for percentages based on unequal numbers (Cochran 1943). Total weights of the largest seedling in each pot were also compared among seed beds by analyses of variance. Scheffé tests (Snedecor and Cochran 1967, p. 271) were used to compare species survival on each seed bed, and Tukey tests (Snedecor 1956, p. 251) were used to compare species weights.

A second growth chamber experiment was conducted under identical conditions, but with additional nutrients to see if seed bed differences were related to nutrient deficiencies. The seed bed materials were initially saturated in nutrient solution,[3/] and equal quantities of this solution were added weekly until the seedlings were harvested. Growth periods, harvesting, data gathering, and statistical analyses were identical in the two experiments.

RESULTS

Nitrogen content in hemlock duff (1.239 percent) was six times greater than in rotten Douglas-fir wood (table 2). Extractable phosphorus (648 parts per million) was seven times greater. These nitrogen and phosphorus contents also greatly exceed the 0.1 to 0.3 percent nitrogen and 10 to 200 parts per million available phosphorus found in virgin forest soils (Wilde 1946). Other nutrients also were more abundant in duff than in rotten wood or a forest soil.

The germination rates of all species were slower on duff than on rotten wood in the first growth chamber experiment, but Douglas-fir was delayed significantly longer than the other species. Variations in seed lot viability make among-species comparisons of germination percentages statistically invalid. Within-species comparisons (table 3) show that seed bed materials did not affect germination percentages.

Within-species survival comparisons show that Douglas-fir survived better on rotten wood in the first experiment, and red alder survival was better on duff. Survival of the other species was not affected by seed bed material. Comparisons of survival among species showed no significant species differences on either duff or rotten wood.

[3/] 1.6 grams $Ca(NO_3)_2$, 1.0 gram KNO_3, 0.5 gram $MgSO_4$, and 0.3 gram KH_2PO_4 per liter of H_2O.

Table 2.--*Chemical analyses of seed bed materials used in the growth chamber and in the field*

Seed bed	Total nitrogen[1/]	Phosphorus		Potassium		Total calcium[6/]	Total magnesium[6/]
		Total[2/]	Extractable[3/]	Total[4/]	Exchangeable[5/]		
	Percent	*Parts per million*					
Growth chamber:							
Hemlock duff	1.239	1,337	648	950	828	2,340	1,585
Douglas-fir wood	.212	123	90	240	218	925	425
Field:							
Hemlock duff	1.096	1,230	325	635	614	1,750	2,325
Douglas-fir wood	.104	72	45	210	210	700	275
Sitka spruce wood	.135	129	45	245	215	940	530
Hemlock wood	.098	72	50	140	108	1,220	550

1/ Kjeldahl.
2/ Colorimetric, after perchloric acid oxidation.
3/ Sodium bicarbonate extraction.
4/ Flame emission after perchloric acid oxidation.
5/ Ammonium acetate extraction.
6/ Atomic absorption after perchloric acid oxidation.

Table 3.--*Average seed germination, survival of germinated seedlings, and weight of largest seedling in a growth chamber, by species and seed bed material*

Species	Average germination			Average survival of germinated seedlings[1/]			Average weight of largest seedling		
	Duff	Rotten wood	Significance of difference[2/]	Duff	Rotten wood	Significance of difference[2/]	Duff	Rotten wood	Significance of difference[2/]
	-Percent-			*-Percent-*			*-Grams-*		
Red alder	80	82	NS	92	66	**	1.42	0.01	**
Douglas-fir	56	78	NS	61	76	*	.53	.13	*
Sitka spruce	42	40	NS	73	91	NS	.49	.03	**
Lodgepole pine	92	92	NS	65	61	NS	.37	.07	**
Western hemlock	79	84	NS	69	62	NS	.29	.03	**
Western redcedar	74	94	NS	56	54	NS	.34	.02	*
Pacific silver fir	28	40	NS	47	54	NS	.29	.12	NS

[1/] Based on number germinating.

[2/] Statistical significance of seed bed difference--NS = not significant, * = significant (p = 0.95), ** = highly significant (p = 0.99).

Seedlings of all species were heavier on duff than on rotten wood. Alder seedlings were significantly heavier than all others on duff, lighter than all others on rotten wood. Douglas-fir and Pacific silver fir seedlings were significantly heavier than all others on rotten wood.

When nutrients were added in the second growth chamber experiment, no seed bed-induced differences in germination rates were observed. Sitka spruce germination was better on rotten wood than on duff, but the germination of other species was not affected by seed bed material (table 4).

Adding nutrients did not significantly affect the relative survival of red alder, western redcedar, or Pacific silver fir on the two seed beds--red alder survival was again better on duff, and the survival of western redcedar and Pacific silver fir remained unaffected by seed bed materials. However, the added nutrients did significantly alter the relative survival of all other species. They all survived better on duff than on rotten wood when nutrients were added. The added nutrients improved growth on rotten wood, but seedlings grown on duff were again heavier than those grown on wood.

Alder seedlings germinating on duff were quite different from those germinating on rotten wood. The germinating seedlings produced abundant root hairs on the duff, and the young roots were unbranched. No root hairs were produced on the rotten wood, and the young roots branched while still above the seed bed surface. Root development remained different on different seed beds as the alder seedlings grew larger--root nodules were produced on duff, but not on rotten wood. These differences in alder germination and root development occurred in both experiments.

FIELD EXPERIMENT

Methods

Seed bed materials were collected, prepared, and sampled as done in the growth chamber experiments, except that three species of rotten wood were used--Douglas-fir, Sitka spruce, and western hemlock. Rotten log species were identified by using a field key (Minore 1966). Rotten wood was then collected from several logs and blended to yield a uniform composite sample for each of the three species. Hemlock duff was used as a fourth seed bed material. The four seed beds were combined with three shade intensities in a completely random, split-plot design in which shade treatments were the main plots, and seed beds were the subplots.

The seed beds and shade treatments were established in a level field on the Cascade Head Experimental Forest at an elevation of 50 meters. Each subplot consisted of a 15-centimeter-deep hole 30 centimeters in diameter. This hole was lined with a bottomless cylinder of copper window screen, then filled with one of the seed bed materials. There were 15 holes for each of the four materials. They were spaced 1.2 meters apart. Hardware cloth cones were

Table 4.--*Average seed germination, survival of germinated seedlings, and weight of largest seedling with added nutrients in a growth chamber, by species and seed bed material*

Species	Average germination			Average survival of germinated seedlings[1/]			Average weight of largest seedling		
	Duff	Rotten wood	Significance of difference[2/]	Duff	Rotten wood	Significance of difference[2/]	Duff	Rotten wood	Significance of difference[2/]
	--Percent--			*--Percent--*			*---Grams---*		
Red alder	88	90	NS	94	61	**	4.15	1.33	**
Douglas-fir	76	76	NS	74	41	*	1.15	.68	*
Sitka spruce	38	74	**	73	59	**	.63	.37	*
Lodgepole pine	96	94	NS	86	43	**	.60	.26	**
Western hemlock	96	96	NS	92	66	**	.30	.20	NS
Western redcedar	88	90	NS	69	46	NS	.83	.22	*
Pacific silver fir	46	44	NS	0	4	NS	--	.11	--

[1/] Based on number germinating.

[2/] Statistical significance of seed bed difference--NS = not significant, * = significant (p = 0.95), ** = highly significant (p = 0.99).

placed over each of the 60 filled holes to provide protection from rodents and birds (fig. 4). These hardware cloth cones alone provided the light shade treatment of 79 percent full sunlight.[4/] Porous Saran plastic shade-screen material placed over the hardware cloth provided the moderate and dense shade treatments of 43 percent and 2 percent full sunlight, respectively. Seed bed materials and shade treatments were randomly distributed, and each seed bed-shade combination was replicated five times.

Figure 4.—Artificial seed beds in the field. Light, moderate, and heavy shade conditions were obtained with the hardware cloth and shade screen cones shown here.

In November 1967, the seed beds were seeded with six species: Douglas-fir, Sitka spruce, lodgepole pine, western hemlock, western redcedar, and Pacific silver fir. With the aid of a plastic template, 10 seeds of each species were sown on each of the 60 subplots in the same random order. They were loosely covered with 1 centimeter of seed bed material immediately after sowing.

The seed beds were not watered, but soil between the subplots was cultivated during the spring and summer of 1968 to prevent weed growth. Seedlings were counted monthly to determine germination percentages. The survivors were harvested in October, when the following counts and measurements were made for each subplot: (1) Number of surviving seedlings, (2) height of tallest seedling of each species, (3) root length of tallest seedling of each species, and (4) ovendry shoot, root, and total weights of tallest seedling of each species. These data were then subjected to analyses of variance. Individual treatment averages were compared by Scheffé tests.

Results

Within-species differences in germination and survival on the four seed beds were small (tables 5 and 6), but initial germination was better on rotten

[4/] All shade intensities were measured at noon on a cloudless day with a Weston Model 756 illumination meter reading at 4,700° K.

Table 5.--*Average seed germination in the field, by species, seed bed material, and shade treatment*[1/]

Species and seed bed	Shade treatment			Average, all shade treatments
	Light	Moderate	Heavy	
	- - - - - - - - - - - - *Percent* - - - - - - - - - - - -			
Douglas-fir:				
Duff	80	54	48	60.7
Douglas-fir wood	62	72	78	70.7
Spruce wood	72	46	60	59.3
Hemlock wood	74	86	52	70.7
Average, all seed beds	72.0	64.5	59.5	--
Sitka spruce:				
Duff	24	36	30	30.0
Douglas-fir wood	46	56	32	44.7
Spruce wood	68	24	22	38.0
Hemlock wood	32	46	28	35.3
Average, all seed beds	42.5	40.5	28.0	--
Lodgepole pine:				
Duff	88	48	54	63.3
Douglas-fir wood	68	68	58	64.7
Spruce wood	76	36	46	52.7
Hemlock wood	44	46	30	40.0
Average, all seed beds	69.0	49.5	47.0	--
Western hemlock:				
Duff	22	18	16	18.7
Douglas-fir wood	48	36	12	32.0
Spruce wood	58	14	18	30.0
Hemlock wood	28	28	14	23.3
Average, all seed beds	39.0	24.0	15.0	--
Western redcedar:				
Duff	30	10	6	15.3
Douglas-fir wood	32	36	16	28.0
Spruce wood	28	36	16	26.7
Hemlock wood	14	38	14	22.0
Average, all seed beds	26.0	30.0	13.0	--
Pacific silver fir:				
Duff	30	28	12	23.3
Douglas-fir wood	26	38	12	25.3
Spruce wood	18	30	18	22.0
Hemlock wood	14	22	12	16.0
Average, all seed beds	22.0	29.5	13.5	--

[1/] Analysis of variance indicated significant differences among shade and seed bed treatments but no significant seed bed-shade or species-shade interactions. Individual treatment averages were not compared.

Table 6.--*Average survival of germinated seeds in the field, by species, seed bed material, and shade treatment*[1/]

Species and seed bed	Shade treatment			Average, all shade treatments
	Light	Moderate	Heavy	
	- - - - - - - - - - - - *Percent* - - - - - - - - - - - -			
Douglas-fir:				
Duff	92	100	71	87.7
Douglas-fir wood	97	98	64	86.3
Spruce wood	83	100	89	90.7
Hemlock wood	95	83	49	75.7
Average, all seed beds	91.8	95.2	68.2	--
Sitka spruce:				
Duff	73	78	20	57.0
Douglas-fir wood	64	93	25	60.7
Spruce wood	72	80	8	53.3
Hemlock wood	53	67	0	40.0
Average, all seed beds	65.5	79.5	13.2	--
Lodgepole pine:				
Duff	94	100	20	71.3
Douglas-fir wood	87	91	21	66.3
Spruce wood	88	100	26	71.3
Hemlock wood	61	88	0	49.7
Average, all seed beds	82.5	94.8	16.8	--
Western hemlock:				
Duff	40	100	0	46.7
Douglas-fir wood	49	88	66	67.7
Spruce wood	40	75	33	49.3
Hemlock wood	81	72	12	55.0
Average, all seed beds	52.5	83.8	27.8	--
Western redcedar:				
Duff	35	62	0	32.3
Douglas-fir wood	21	61	25	35.7
Spruce wood	40	84	17	47.0
Hemlock wood	25	32	0	19.0
Average, all seed beds	30.2	59.8	10.5	--
Pacific silver fir:				
Duff	62	100	28	63.3
Douglas-fir wood	65	88	61	71.3
Spruce wood	73	80	50	67.7
Hemlock wood	100	67	83	83.3
Average, all seed beds	75.0	83.8	55.5	--

[1/] Disproportionate subclass frequencies, percentages based on unequal numbers, and unequal variances made statistical analyses of these data impractical.

Douglas-fir wood than on other seed beds. Duff produced the tallest and heaviest seedlings (tables 7 and 8). Root lengths were not significantly affected by seed bed material (table 9).

Germination of all species was poorest in heavy shade and best in light or moderate shade (table 5). Survival was poorest in heavy shade and best in moderate shade (table 6). Shading did not significantly affect seedling heights (table 7), but it did affect root lengths--roots were shorter in heavy shade (table 9). Total seedling weights were also affected by shade intensity. Seedlings of all species except lodgepole pine were heaviest in light and moderate shade and lightest in heavy shade. Lodgepole pine seedlings were heaviest in light shade and lightest in moderate and heavy shade.

Inherent growth differences made species comparisons difficult, but lodgepole pine and Douglas-fir seemed best able to utilize light shade. Pacific silver fir seemed best able to tolerate heavy shade and was least affected by the seed bed differences.

The contrasting effects of seed bed and shade on seedling heights and root lengths constitute the most important results of this field experiment. All species responded similarly. Seedling heights were significantly affected by seed bed but not by shade. Root lengths were affected by shade but not by seed bed. These contrasting responses to shade and seed bed treatments resulted in higher shoot-root ratios for heavily shaded duff than for the other treatment combinations. Higher shoot-root ratios benefit seedlings growing in shady, moist habitats by increasing photosynthesis per unit of total seedling weight (Borman 1958). The observed occurrence of heavily shaded native conifer seedlings only on thick duff accumulations may be the result of a seed bed-induced higher shoot-root ratio that is essential for survival in low light conditions.

Table 7.--*Average height of largest surviving seedling in the field, by species, seed bed material, and shade treatment*[1/]

Species and seed bed	Shade treatment			Average, all shade treatments
	Light	Moderate	Heavy	
	Centimeters			
Douglas-fir:				
Duff	11.7	9.3	5.9	9.0
Rotten wood[2/]	4.8	4.1	5.0	4.6
Average, all seed beds	8.2	6.7	5.4	--
Sitka spruce:				
Duff	2.2	3.5	2.0	2.6
Rotten wood[2/]	1.3	1.6	2.0	1.6
Average, all seed beds	1.8	2.5	2.0	--
Lodgepole pine:				
Duff	8.4	6.1	4.0	6.2
Rotten wood[2/]	4.7	4.2	4.3	4.4
Average, all seed beds	6.6	5.2	4.2	--
Western hemlock:				
Duff	3.7	4.1	--	--
Rotten wood[2/]	1.9	1.9	1.5	1.8
Average, all seed beds	2.8	3.0	--	--
Western redcedar:				
Duff	4.3	4.0	--	--
Rotten wood[2/]	2.0	1.5	1.2	1.6
Average, all seed beds	3.2	2.8	--	--
Pacific silver fir:				
Duff	3.2	3.5	2.5	3.1
Rotten wood[2/]	2.7	2.9	2.9	2.8
Average, all seed beds	3.0	3.2	2.7	--

[1/] Averages within the same rectangle are not significantly different.

[2/] Average, all 3 wood species. They did not differ significantly.

Table 8.--*Average weight of largest surviving seedling in the field, by species, seed bed material, and shade treatment*[1/]

Species and seed bed	Shade treatment			Average, all shade treatments
	Light	Moderate	Heavy	
	- - - - - - - - - - - Grams - - - - - - - - - - -			
Douglas-fir:				
Duff	0.568	0.389	0.024	0.327
Rotten wood[2/]	.173	.111	.025	.103
Average, all seed beds	.370	.250	.024	--
Sitka spruce:				
Duff	.032	.039	.003	.025
Rotten wood[2/]	.015	.016	.002	.011
Average, all seed beds	.024	.028	.002	--
Lodgepole pine:				
Duff	.752	.310	.009	.357
Rotten wood[2/]	.230	.123	.012	.122
Average, all seed beds	.491	.216	.010	--
Western hemlock:				
Duff	.052	.063	--	--
Rotten wood[2/]	.019	.020	.002	.014
Average, all seed beds	.036	.042	--	--
Western redcedar:				
Duff	.057	.050	--	--
Rotten wood[2/]	.011	.012	.002	.008
Average, all seed beds	.034	.031	--	--
Pacific silver fir:				
Duff	.185	.137	.025	.116
Rotten wood[2/]	.093	.122	.028	.081
Average, all seed beds	.139	.130	.026	--

[1/] Averages within the same rectangle are not significantly different.

[2/] Average, all 3 wood species. They did not differ significantly.

Table 9.--*Average root length of largest surviving seedling in the field, by species, seed bed material, and shade treatment*[1/]

Species and seed bed	Shade treatment			Average, and shade treatments
	Light	Moderate	Heavy	
	- - - - - - - - - - *Centimeters* - - - - - - - - - -			
Douglas-fir:				
Duff	24.4	20.3	8.4	17.7
Rotten wood[2/]	21.2	20.0	9.7	17.0
Average, all seed beds	22.8	20.2	9.0	--
Sitka spruce:				
Duff	8.6	9.8	3.0	7.1
Rotten wood[2/]	7.7	7.2	3.2	6.0
Average, all seed beds	8.2	8.5	3.1	--
Lodgepole pine:				
Duff	23.9	12.7	1.9	12.8
Rotten wood[2/]	23.8	18.9	5.3	16.0
Average, all seed beds	23.8	15.8	3.6	--
Western hemlock:				
Duff	15.5	14.5	--	--
Rotten wood[2/]	10.7	12.3	4.0	9.0
Average, all seed beds	13.1	13.4	--	--
Western redcedar:				
Duff	16.7	15.7	--	--
Rotten wood[2/]	10.4	11.1	3.2	8.2
Average, all seed beds	13.6	13.4	--	--
Pacific silver fir:				
Duff	19.8	19.6	6.8	15.4
Rotten wood[2/]	16.2	16.2	7.6	13.3
Average, all seed beds	18.0	17.9	7.2	--

[1/] Averages within the same rectangle are not significantly different.

[2/] Average, all 3 wood species. They did not differ significantly.

SUMMARY AND DISCUSSION

Nutrients are more abundant in duff than in rotten wood. Coastal tree seedlings grow larger in duff than in rotten wood, even when extra nutrients are added. However, seedlings are usually larger and more abundant on rotten logs than on the duff-covered forest floor under coastal conifer stands where there is less than 40 percent full sunlight. This apparent paradox seems to be the result of differential duff accumulation. Duff layers accumulate on both rotten logs and soil, but they are thicker on those rotten logs that support seedlings than they are on mineral soil.

Where more than 40 percent full sunlight occurs under coastal stands, duff-covered soil and rotten logs seem to be equally suitable seed beds. This apparently results from better root growth--seedling roots grow longer in light shade than in heavy shade. The extra nutrient concentrations present in the thick duff layers that accumulate over rotten wood seem to be essential where heavy shade limits root growth and less important where light shade does not limit it.

The germination and early growth of coastal tree species are not affected differently by differences in organic seed beds, with two minor exceptions. Douglas-fir seed germination is delayed longer than that of other species on duff, and alder seedlings germinating on rotten wood do not develop root hairs or nodules.

Field observations indicate that neither rotten wood nor duff-covered soil are good seed beds where complete removal of the overstory provides full sunlight. Such sun-loving species as red alder are, therefore, not usually found on duff seed beds, even though they grow well on duff when supplemental moisture is supplied. Organic seed beds are most important in shaded conditions such as those that prevail under a lightly thinned shelterwood stand.

Type of organic seed bed probably does not affect the species composition of forest regeneration under a lightly thinned shelterwood stand in coastal Oregon. Where light shelterwood cutting will result in a shaded seed bed, duff accumulations should be preserved whenever possible. This will benefit all conifer species by providing extra nutrients for the short-rooted seedlings produced under low light conditions.

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ARASAN IN ENDRIN TREATMENTS TO PROTECT DOUGLAS-FIR SEED FROM DEER MICE

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ABSTRACT

In laboratory bioassays, coating with endrin reduced consumption of Douglas-fir seed by deer mice. Coating with Arasan did not lower seed consumption, but endrin plus Arasan reduced feeding to levels comparable with endrin alone. Substitution of talc for Arasan produced similar results. Endrin had little effect on seed germination, but addition of Arasan caused a significant reduction. Increasing amounts of latex adhesive used to bind chemicals to the seed decreased the protective effects of endrin treatments.

Keywords: Endrin, Arasan, rodenticides, Douglas-fir, biological assay.

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INTRODUCTION

Since the 1950's, endrin[1/] has been widely used by foresters to protect conifer seed from seed-eating rodents (Radwan et al. 1970). A standard treatment consisting of 0.5 percent endrin, an adhesive, 2 percent Arasan (tetramethylthiuram disulphide [TMTD]), and a coloring material, was recommended by the U.S. Bureau of Sport Fisheries and Wildlife in 1956 (Anonymous 1956).

Although field-sown seed treated with endrin germinated successfully in early trials (Dimock 1957, Hooven 1957), many seeding failures have occurred. Consequently, the treatment has been variously modified by changing one or more of the components according to regional or local suggestions, usually with little or no documented basis for the changes.

In the Pacific Northwest, during most of the 1960's, the protective formulation used for Douglas-fir (*Pseudotsuga menziesii*) seed usually contained 1 percent endrin and no Arasan. Apparently, Arasan was eliminated because bird predation was considered minimal and some tests indicated that the chemical did not add significantly to the protective value of the treatment (Dick et al. 1958) and interfered with germination (Shea 1961). During the late 1960's, however, many foresters have reverted to the 1956 formulation (0.5 percent endrin and 2 percent Arasan) despite the lack of new information.

In the South, where much seed is taken by birds in addition to that destroyed by rodents, Arasan (up to 8 percent) is an important component in seed treatments. Much seed of the southern pines (*Pinus* spp.), therefore, has been successfully treated with an endrin-Arasan formulation (Mann 1968).

In this study we reevaluated endrin, Arasan, and endrin-Arasin treatments on Douglas-fir seed using bioassay and germination tests. We used 0.5 percent endrin and 2 to 8 percent Arasan. To ascertain the role of Arasan further, we substituted talc, an inert compound, for the chemical in four tests. In addition, we determined effects of different levels of adhesive on the endrin and endrin-Arasan treatments.

MATERIALS AND METHODS

Seed

One medium-elevation seed lot of Douglas-fir from Pierce County, Washington, was used for all tests. The seed was collected in 1965 and stored at -4° C. During the summer of 1969, 2 pounds of seed were drawn from storage and divided into 1/10-pound subsamples for the different treatments.

Chemicals

Endrin 50-WP (50-percent wettable powder) from Stauffer Chemical Company and Arasan 42-S (42-percent liquid thiram) from the DuPont Company were the active ingredients and talc from the Matheson Company served as an inert compound. Dow Latex 512-R, from the Dow Chemical Company, served as the adhesive, and aluminum powder was used to minimize seed clustering and to identify treated seed.

1/ Mention of chemical compounds and chemical companies does not represent endorsement by the U.S. Forest Service or the Department of Agriculture.

Seed treatments

Seeds were treated as follows:

1. *Control (untreated):* Seed was not chemically treated.

2a, 2b, 2c. *0.5 percent endrin:* Seed was coated with endrin at a concentration of 0.5 percent by weight (1.0 percent of Endrin 50-WP) using 10 ml. of diluted adhesive and 1.2 g. aluminum powder per 100 g. seed. To test the effect of different degrees of binding the chemical to the seed, three treatments were obtained by using different levels of the adhesive. This was achieved by 1:9 (a), 1:4 (b), and 1:1 (c) volume dilutions of the adhesive with water before use.

3. *8.0 percent Arasan:* Seed was coated with a volume of liquid Arasan 42-S providing solid Arasan at 8 percent by weight. Undiluted latex and water were added to the Arasan liquid to make the total volume of the mixture and the adhesive solids the same as in treatment 2a. Also, wet seed was coated with 1.2 g. aluminum powder per 100 g. seed.

4a, 4b, 4c. *0.5 percent endrin + 8.0 percent Arasan:* Combinations of treatments 2 and 3, using 1.2 g. aluminum powder per 100 g. seed and adding undiluted latex and water, so that amounts of adhesive solids and total volumes of treatment mixture were the same as in treatments 2a, 2b, and 2c, respectively.

5a, 5b, 5c. *0.5 percent endrin + 4.0 percent Arasan:* Same as treatments 4a-c, but with half the amounts of Arasan.

6a, 6b, 6c. *0.5 percent endrin + 2.0 percent Arasan:* Same as treatments 4a-c, but with one-fourth the amounts of Arasan.

7. *8 percent talc:* Seed was coated with talc at 8 percent by weight. The adhesive and aluminum were the same as in treatment 2a.

8. *0.5 percent endrin + 8 percent talc:* A combination of treatments 2a and 7.

9. *0.5 percent endrin + 4 percent talc:* Same as treatment 8, but with half the amount of talc.

10. *0.5 percent endrin + 2 percent talc:* Same as treatment 8, but with one-fourth the amount of talc.

In all treatments except the control, seeds were wet with slurries of the chemicals in the adhesive, covered with a thin layer of aluminum powder, and allowed to dry overnight under a hood.

Bioassay

Two trials were conducted--consumption of: (1) untreated (control) seed was compared with that coated with either endrin, Arasan, talc, and endrin plus Arasan or talc, and (2) seed treated with endrin alone was compared with seed treated with endrin-Arasan at three levels of adhesive.

Deer mice (*Peromyscus maniculatus*) live-trapped near Tumwater, Washington, were used in all bioassays. Briefly, 10 seeds of one treatment were fed daily to each of 10 freshly caught mice for 5 consecutive days. Seed consumption was recorded daily and the numbers of dead mice were noted each day during the test and for 2 days following. Water and a commercial pelleted ration were offered *ad libitum* before and during each test. All bioassays were conducted in October, November, and December 1970.

Germination

Arasan and talc were ineffective in the bioassays, and the endrin-talc treatments had no practical importance; thus seeds from treatments 3, 7, 8, 9, and 10 were not germinated. Of the remainder, seeds from treatments 2a, 4a, 5a, 6a, and control were selected for testing to evaluate the effects of endrin and endrin-Arasan combinations on germination and seedling production.

Eight replicates of 100 seeds each were germinated on perlite at 24° ± 1° C. after stratification for 21 days at 3° to 5° C. Four replicates were stratified before treatment and the other four after treatment. Germinants were counted at weekly intervals for 4 weeks.

To study seedling production and growth, replicates similar to those of the perlite tests, but of 35 seeds each, were planted about 1/8 inch deep in 4- by 4-inch pots containing equal amounts of soil, vermiculite, and peat moss. The pots were placed under growth chamber conditions described in Radwan et al. (1970), and after 50 days resulting seedlings were counted.

Statistical analysis

Bioassay and germination data were subjected to analysis of variance after arc-sine transformation. Means were separated according to Tukey's test (Snedecor 1961), or appropriate orthogonal comparisons were made as required.

RESULTS

Bioassay

Arasan or talc applied alone had no effect on seed consumption, but endrin and endrin plus Arasan or talc at all levels significantly reduced feeding (table 1). More importantly, seed consumption was not significantly different among the endrin, endrin-Arasan, and endrin-talc treatments.

Increasing the ratios of adhesive to water caused significant increases in consumption of endrin and endrin-Arasan treated seed, but differences among treatments within a single level of adhesive were not significant (table 2).

Mortality of mice was low in all bioassays. Only six of the 180 test mice died as an apparent result of chemical treatments.

Germination

Within each treatment, germination on perlite and in soil differed little between seed stratified before and after treatment. This indicates that chemicals present on the seed during stratification had negligible effects on germination. Consequently, results were averaged for each treatment as shown in table 3. Also, germination on perlite was comparable with that in soil for all treatments.

Germination of treated seed was lower than the controls; a slight reduction in germination resulted from endrin, and a further significant decrease was evident when Arasan was present. Gross examinations of seedling tops and roots, however, indicated that seedling growth was not affected by the endrin or endrin-Arasan treatments.

DISCUSSION AND CONCLUSIONS

In this study we were unable to substantiate Arasan's repellency to deer mice (Spencer 1960). Our bioassay results show that action of Arasan was similar to

Table 1.--*Consumption by deer mice of untreated and endrin-, Arasan-, and talc-coated Douglas-fir seed and resulting animal mortality*

Treatment	Treatment number	Seed consumption[1/]	Animal mortality
		- - - - - *Percent* - - - - -	
Control	1	100 x	0
0.5 percent endrin	2 a	43 y	0
0.5 percent endrin + 2.0 percent Arasan	6 a	50 y	0
0.5 percent endrin + 4.0 percent Arasan	5 a	50 y	0
0.5 percent endrin + 8.0 percent Arasan	4 a	39 y	0
8.0 percent Arasan	3	99 x	0
0.5 percent endrin + 2.0 percent talc	10	52 y	20
0.5 percent endrin + 4.0 percent talc	9	50 y	0
0.5 percent endrin + 8.0 percent talc	8	42 y	20
8.0 percent talc	7	99 x	0

[1/] 10 animals, 10 seeds per animal per day, 5-day test. Means followed by the same letter do not differ significantly at the 5-percent level, using Tukey's test.

that of talc--an inert compound. Arasan alone was completely ineffective against deer mice and, when mixed with endrin, did not enhance effectiveness of the treatment. The chemical also caused significant reductions in germination in agreement with Shea (1961).

Deer mice do not eat whole conifer seed--they remove seedcoats to reach and consume the "endosperms." Thus, coated repellants are contacted and may be ingested during the hulling process. Clearly, the amount of repellant available to the animal would depend upon the concentration of the chemical in the coating and the degree of binding to the seedcoat by the adhesive. Accordingly, at the same level of adhesive (table 1), endrin was more concentrated in the coating and more tightly bound to the seed when the chemical was used alone than when it was present with other additives.

Adding Arasan (or talc) to the coating decreased the concentration of endrin and its binding to the seed. Thus, while there was less endrin per unit weight of coating in presence of Arasan (or talc), the chemical was less tightly bound to the seed and more available to the mice. We believe that this counteraction between endrin concentration in the coating and degree of binding by the adhesive was the cause for similar effectiveness of the endrin and endrin-Arasan treatments when the same amount of adhesive was used. We also suggest that the effectiveness in seed protection previously attributed to Arasan by us and others probably resulted from the use of different seed-treatment methods and (or) ingredients. For this study, we coated our seed uniformly using one method of treatment throughout, and we used the liquid Arasan 42-S rather than a solid formulation.

Table 2.--*Consumption by deer mice of Douglas-fir seed coated with endrin and endrin-Arasan at three levels of adhesive and resulting animal mortality*

Treatment	Treatment number	Seed consumption[1/]	Animal mortality
		Percent	
0.5 percent endrin:			
1:9 adhesive	2 a	43 x	0
1:4 adhesive	2 b	66 y	0
1:1 adhesive	2 c	86 z	10
0.5 percent endrin + 2.0 percent Arasan:			
1:9 adhesive	6 a	50 x	0
1:4 adhesive	6 b	63 y	0
1:1 adhesive	6 c	93 z	0
0.5 percent endrin + 4.0 percent Arasan:			
1:9 adhesive	5 a	50 x	0
1:4 adhesive	5 b	63 y	0
1:1 adhesive	5 c	94 z	0
0.5 percent endrin + 8.0 percent Arasan:			
1:9 adhesive	4 a	39 x	0
1:4 adhesive	4 b	57 y	0
1:1 adhesive	4 c	95 z	10

[1/] 10 animals, 10 seeds per animal per day, 5-day test. Means followed by the same letter do not differ significantly at the 5-percent level, using Tukey's test.

Table 3.--*Germination of treated and untreated Douglas-fir seed on perlite and in soil*

Treatment	Treatment number	Germination[1/]	
		Perlite	Soil
		Percent	
Control	1	83	80
0.5 percent endrin	2 a	82	73
0.5 percent endrin + 2.0 percent Arasan	6 a	77	70
0.5 percent endrin + 4.0 percent Arasan	5 a	74	68
0.5 percent endrin + 8.0 percent Arasan	4 a	72	68

[1/] In each column, orthogonal comparisons at the 5-percent level show that treatments containing Arasan are significantly different from those without the chemical, but there are no differences between control and endrin-only treatments.

The importance of the adhesive and the ineffectiveness of Arasan are illustrated further in table 2. Within the endrin and each of the endrin-Arasan treatments, increasing adhesive amounts increased seed consumption. However, differences among the four treatments within each of the three adhesive levels used were not significant.

There appears to be no justification for adding Arasan to endrin treatment to protect Douglas-fir seed from deer mice. Whether Arasan provides protection from other seed-eating rodents, birds, or fungi commonly found in the Douglas-fir region is problematical. Preliminary data from a field study currently underway in western Oregon and Washington show that seed treated with endrin alone is equally as effective in producing seedlings as that treated with endrin plus Arasan (unpublished data). Dick et al. (1958) came to a similar conclusion.

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accelerated roadbuilding on the north umpqua -- an economic analysis

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ABSTRACT

This study evaluates the economic desirability of accelerated roadbuilding for access to old-growth timber on a unit of the Umpqua National Forest in Oregon. As of 1966, four accelerated roadbuilding alternatives were found economically inferior to the then current rate of construction. Only in the case of substantial, continuing inflation were projected rates of return on investment for accelerated roadbuilding above 6 percent compound interest.

The inclusion of nontimber benefits and costs, changes in price and cost levels since 1966, and recent improvements in logging technology do not appear to alter this study's results appreciably.

Combined with the results of recent, published studies, the findings on the North Umpqua suggest that accelerated roadbuilding is not an attractive investment opportunity for National Forests in the Douglas-fir region.

Keywords: Forest roads, forestry economics, logging.

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SUMMARY

This study evaluates the economic desirability of accelerated roadbuilding on the North Umpqua unit of the Umpqua National Forest in southwestern Oregon.

Four alternatives, ranging from 1-1/3 to 6 times the current rate of roadbuilding in 1966, were evaluated by comparing their estimated additional benefits and costs. Additional benefits included timber volume from mortality salvage, prelogging, and thinning. Additional costs were interest charges and road maintenance from the time roads were completed under an accelerated program until they would have been completed at the 1966 rate.

When only benefits from timber harvesting were considered, no accelerated rate of roadbuilding was economically justified. The best alternative promised less than a 4-percent rate of return on investment. Reasonable changes in price and cost assumptions did not result in attractive rates of return for accelerated roadbuilding, with one exception: substantial, continuing inflation could raise rates of return to 7 percent or higher.

Inclusion of nontimber benefits and costs appears to further reduce the economic desirability of accelerated roadbuilding, primarily due to higher construction costs needed to limit damage to fisheries and water resources.

Improvements in logging technology and changes in price and cost levels since 1966 would not appreciably alter the results of this study.

Combined with the results of recent, published studies, the findings on the North Umpqua strongly suggest that accelerated roadbuilding is not an attractive investment opportunity for National Forests in the Douglas-fir region.

PURPOSE AND SCOPE OF STUDY

It has been suggested (Fedkiw 1961, Helburn 1947, McMahon 1961, Morse 1962, Public Land Law Review Commission 1970, Richen 1961, USDA Forest Service 1953)[1/] that public investment in an accelerated roadbuilding program on the National Forests would yield great benefits to the American economy. Allegedly, a faster rate of road construction would permit a higher annual cut of timber, increased utilization of non-timber resources, and improved protection and management of the National Forests. The value of these additional benefits is expected to exceed the additional expenditures necessary to attain them. For example, Fedkiw (1961) suggests the availability of an additional 1 to 2 billion board feet per year and rates of return on investment as high as 10 percent in the Pacific Northwest.

Despite these predictions of great economic benefits of accelerated roadbuilding, the economic analysis of road scheduling has been a neglected aspect of forest road planning. Road location and design have been subject to fairly sophisticated economic analyses (Matthews 1942, Silen 1955, Larsson 1959). Helburn (1947) argued for fast enough roadbuilding to harvest the allowable cut. Descriptive papers (Fedkiw 1961 and 1964, Richen 1961) have outlined the potential of faster roadbuilding. But until the "Douglas-fir Supply Study" (USDA Forest Service 1969) and the paper by Schallau (1970), there had been no published economic analyses of forest road scheduling.

Is accelerated roadbuilding on the National Forests economically justified? This study provides a method for answering this question and applies it to a sample National Forest unit, using data available as of 1966.

Roadbuilding an Important Investment

Road construction on the National Forests is a vital first step in forest management and protection. Roadbuilding is also the forest manager's most expensive single investment. In 1965, the planned road system on the National Forests was 513,503 miles, including existing roads (Ketcham 1965). Construction or reconstruction of 384,333 miles, mostly in the West, remained to complete the system. If these roads cost $25,000 per mile, an investment of $9.6 billion was needed.

Until the early 1950's, lack of access roads in the National Forests prevented harvest of the full annual allowable cut of timber[2/] (USDA Forest Service 1953). At the same time, demand for timber was strong, forcing stumpage prices up and creating strong pressures on the Forest Service to improve access and sell more timber (USDA Forest Service 1962). One result of this pressure was increased appropriations for Forest Service roads, which permitted attainment of the full allowable cut on most forests by the middle 1950's (Cliff 1956).

[1/] *Names and dates in parentheses refer to Literature Cited, p. 18-20.*

[2/] *The volume of timber that may be cut, under management, in a given year.*

The demand for timber has not slackened. For example, the average all-species stumpage price per thousand board feet (M bd. ft.) in western Oregon and Washington rose from $12.24 in 1950 to $37.05 in 1966, whereas total timber harvested increased only 13 percent during the same period (Hamilton 1970). Increased demand has produced continuing pressures on the Forest Service to sell more timber. These pressures now are directed at raising the allowable as well as the actual cut. One possibility of raising the cut is through accelerated roadbuilding.

Economically Sound Road Scheduling Decisions Needed

Road scheduling is the "when" of road construction as opposed to the "where" or the "what kind"; that is, it is concerned with the rate of roadbuilding rather than with road location or road design. The rate of roadbuilding can be expressed as the length of time to complete a given road network or, equivalently, the length of road completed in a given period of time. For example, if it takes 10 years to complete a road system of 1,000 miles, the rate of construction is either 1/100 year per mile or 100 miles per year.

If funds are available, the rate of roadbuilding is variable over a wide range, from no roadbuilding at all to a rate that would complete the system in only a year or two. Economic criteria can be used to determine an optimum rate of roadbuilding by comparison of the relative costs and benefits of alternatives throughout the range.

Building roads faster than needed for harvest of the annual allowable cut has been termed "advance roading" by Fedkiw (1961, 1964). Roads are built some time in advance of the final harvest cut for the primary purpose of removing volume not included in the calculated allowable cut. In 1966, this nonchargeable volume included mortality salvage, prelogging, and intermediate cuts to capture potential mortality.

Because timber access roads will eventually be constructed anyway, the only costs attributable to building them in advance are interest on construction costs until the time they would have been needed for final harvest cutting and their maintenance for the same period of time.

Available Budget Limits Roadbuilding Rate

Increasing the rate of roadbuilding on the National Forests would require greater spending until the road system was completed, even though total construction costs might be equal whether the system was built rapidly or slowly. But the amount appropriated for National Forest road construction is strictly limited during a given year, as is the allocation of these funds to individual National Forest units.

In practice, there is some flexibility in the road construction budget for an individual unit. To the extent that timber purchasers build roads as part of timber sale contracts, the road construction budget is increased. The amount of increase possible for a given sale can be calculated as $V(AP - MP)$, where V is the total timber volume, AP is the appraised price as if the roads were in place, and MP is the minimum price that the Forest Service will accept for its timber ($2 per M bd. ft. for Douglas-fir in

1966). Increasing the road allowance can lower the appraised price from a maximum of *AP* all the way to the minimum price. Thus, the Forest Service can manipulate sale size and location subject to appraised and minimum price constraints. Some advantage is taken of this opportunity by the staggered-setting method of timber harvesting practiced in the Douglas-fir region. But even if maximum advantage were taken of this opportunity, there is still a ceiling on the amount annually available for roadbuilding. This ceiling can be removed only by increased appropriations.

Case Study Approach Required

No single rate of road construction is optimum for every National Forest. Because conditions for road construction, timber management, and timber marketing are so variable from place to place, relatively small geographic units must be examined and the optimum rate of roadbuilding determined for each. For example, the results of a road scheduling study are expected to be quite different for young-growth versus old-growth forests, for areas of low versus high road construction costs, and for competitive versus noncompetitive timber market conditions. Thus, the optimum rate of road construction should not be calculated on a regionwide or nationwide basis but should be determined locally.

The North Umpqua unit of the Umpqua National Forest in southwestern Oregon was selected as the site of this study. The unit is typical of much National Forest land in the Douglas-fir region, containing predominantly overmature timber, much of it inaccessible.

The North Umpqua unit is composed of the Diamond Lake, Glide, and Steamboat Ranger Districts, all of which are drained by the North Umpqua River. No other National Forest land lies within the same basin. Thus, the unit boundaries coincide with the boundaries of a logical and complete road system.

The unit occupies about 575,000 acres, roughly 497,000 acres of which are classified as commercial forest land. This acreage supports 18 billion board feet of timber, about two-thirds of which is Douglas-fir. About 93 percent or nearly 17 billion board feet of the total volume is currently merchantable sawtimber 100 years of age or older, and about half of this 17 billion is at least 200 years old. Average site index is a medium-to-high site IV, fairly low compared with the region as a whole. Only about 30 percent of the planned road system was in place as of 1966. At the present rate of construction, 75 miles per year, completion of this road system will require 30 years.

DEVELOPING THE BASIS FOR EVALUATING ACCELERATED ROADBUILDING

Roads on the National Forests are a public investment, whether they are built with appropriated funds or by purchasers of Federal timber. In the latter case, the price paid for timber is less by the estimated roadbuilding cost than if the timber had been sold with the roads already in place.

If they are to contribute to maximizing public welfare, investments in National Forest roads should be economically efficient. In particular, roads should be built at

a rate that maximizes net returns, with costs and returns discounted at compound interest to make them comparable over time.

The following steps are required to rank alternative roadbuilding schedules by their economic desirability:

1. Specify the alternative rates of road construction to be examined, including the present rate.

2. Collect data on benefits over time for each alternative.

3. Collect data on costs over time for each alternative.

4. Subtract the annual benefits and costs for the present rate from the corresponding annual benefits and costs of each of the faster rates.

5. Calculate appropriate measures of investment worth for each accelerated rate of roadbuilding.

6. Rank the alternatives by each measure.

The optimum roadbuilding rate will be that rate having the highest positive present net worth at the appropriate discount rate. If no accelerated rate has a positive present net worth, the present roadbuilding rate will be defined as optimum. Rates of return and benefit cost ratios will be used as supplementary measures of economic efficiency.

Alternative Rates of Road Construction

At the beginning of 1966, there were 894 miles of road on the North Umpqua. Based on the assumption that 4 miles of permanent roads are required per section (640 acres) for complete access to timber stands,[3/] the planned road system for the North Umpqua is 3,109 miles, to serve 497,388 acres of commercial forest land (excluding the lodgepole pine type). Thus, 2,215 miles remained to be completed. At the then-current rate of roadbuilding of 75 miles per year, about 30 years would be required to complete the road system. This rate is used as the base against which the accelerated alternatives are measured.

ALLOWABLE CUT AND PATCH CUTTING LIMITATIONS

Only rates of roadbuilding faster than 75 miles per year are considered in this study. It is assumed that this rate is required to harvest the annual allowable cut of timber. Not to harvest the full allowable cut would violate Forest Service policies and reduce the economic return from the North Umpqua.

3/ A planned road density of 4 miles per section is specified in the Timber Management Plan (TerBush and Kampmann 1961). At this density, on flat ground, a 50-acre square clearcut centered on a road would extend exactly halfway to a parallel, adjacent road.

Although it would be possible to maintain the current allowable cut on the North Umpqua by building roads at less than 75 miles per year, doing so would prevent full application of the patch clearcutting system of timber harvest. This system has been adopted for silvicultural, fire protection, and esthetic reasons. As practiced on the North Umpqua, patch cutting harvests timber in 40- to 60-acre clearcut blocks. The result is a checkerboard pattern of timber harvest. This pattern requires building roads past some timber in order to reach the next cutting unit. As long as these "leave units" or uncut stands are bypassed, the allowable cut cannot be reached with a rate of road construction slower than 75 miles per year.

FOUR ACCELERATED RATES EVALUATED

Four alternatives to the present rate of roadbuilding are evaluated. They range from 1-1/3 to 6 times the present rate as shown in the following tabulation.

Miles per year	Years to complete system	Multiple of present rate
75	29.5	1.0
100	22.2	1.33
150	14.8	2.0
250	8.9	3.33
450	4.9	6.0

The time period over which benefits and costs are estimated must be long enough to include any differential effects of the five rates of roadbuilding. In one sense, each alternative is completed when the road system is finished. But, in another sense, an alternative is never completed because the effects of roadbuilding permanently change the character and management of a forest. For correct comparison of the five alternatives, benefits and costs for each must be estimated for at least 30 years, the time required to complete the road system at the slowest rate.

Costs and benefits after the first 30 years are assumed equal for each of the five roadbuilding plans. Although this assumption is not strictly correct, the importance of any differences beyond the 30th year is substantially reduced by discounting. For example, a 10-percent difference in net benefits between plans in the 31st year is only a 2-percent difference in present value at 5-percent interest or a 0.6-percent difference at 10-percent interest.

Uncertainty in predicting benefits and costs over time is another reason for cutting the comparison off at 30 years. Also, changes in prices or costs over time may obscure any differences that occur because of differing forest structures 30 years hence.

Determining Changes in Timber Harvesting Due to Accelerated Roadbuilding

This section quantifies changes in timber harvesting attributable to accelerated roadbuilding. Nontimber impacts, which are not readily measurable in dollars, are discussed separately.

For the most part, the volume harvested is limited by a Forest Service-established allowable cut. Because this cut is based upon all merchantable timber, without regard to whether it is presently accessible, changing the rate of road construction has little effect on the volume harvested.

Because the present rate of roadbuilding, 75 miles per year, is enough to harvest the annual allowable cut, the only increased volume attributable to advance roading is that not included in the present allowable cut base. As of 1966, the regulated allowable cut for the North Umpqua was 192.3 million board feet per year. A separately regulated cut of 9 million board feet was prescribed for landscape management areas primarily used for recreation. An unregulated cut of 5,700 board feet of dead timber was expected to be removed annually as "mortality salvage." This unregulated volume, which is neither a goal nor a limit, is the key variable in justifying accelerated road construction on an old-growth National Forest.

About 70 percent of total acreage of the North Umpqua is in the Douglas-fir type, with the remainder in the associated species type. Because volumes per acre and stumpage prices differ substantially between types, volumes are recorded for each.

Timber is removed from the North Umpqua by several methods of cutting. These include clearcutting, mortality salvage, thinning, and selective cutting in landscape management areas. A fifth cutting method, prelogging, is assumed possible as a result of accelerated roadbuilding.

SALVAGE CUTTING

The goal of salvage cutting is to remove dead or dying timber that would otherwise be lost to decay if left for the final harvest cut. In any old-growth forest, trees are continually dying, thereby adding to the volume of salvable dead timber.[4/] But, because of decay, the volume of salvable dead timber is constantly reduced. It is assumed that the rate of addition to salvable dead volume through mortality equals the rate of attrition through decay. Thus, the amount of salvable dead volume on the North Umpqua is assumed to remain constant in areas not under management.

The effect of accelerated roadbuilding is to open up areas for salvage of accumulated mortality earlier than would be possible at the present rate of construction. Because this volume is removed earlier, it has a higher present value. And the faster the accumulated mortality is harvested, the sooner a program of periodically salvaging current mortality can begin.

Salvage of accumulated mortality is possible in two locations: adjacent to roads and adjacent to clearcut perimeters. For all rates of road construction, roadside salvage is assumed to be carried out within 3 chains of each side of every mile of

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4/ Salvable dead timber is defined as standing or down dead trees at least 11.0 inches in diameter breast high (d.b.h.) which contain at least 25 percent merchantable board-foot volume.

new road,[5] or on 48 acres per mile, or 192 acres per section, or one-third of total acreage.[6] Salvage is assumed possible to a distance of 3 chains from clearcut perimeters on the 60 percent of acreage with slopes under 37.5 percent. For the average size clearcut of 50 acres, 17.4 acres of perimeter can be salvage cut, or 0.35 acre of perimeter for every acre of clearcut.

Salvage operations remove about 700 board feet[7] per acre of unregulated volume from roadside and clearcut perimeter acreage. Following initial salvage, roadside acreage can be resalvaged every 10 years for 75 percent of current mortality. Depending on forest type, volumes removed will be from 480 to 560 board feet per acre. Because salvage operations on the North Umpqua usually remove about 3,000 board feet per acre, considerable chargeable volume is removed at the same time. Removal of chargeable volumes in salvage operations introduces interdependency between clearcutting and salvage cutting. Faster rates of road construction result in a higher proportion of salvage to clearcutting.

PRELOGGING

Prelogging is the removal prior to clearcutting of small-diameter trees (up to 18 or 20 inches d.b.h.) that would otherwise be broken up and left as slash in a normal clearcut operation. It is assumed that no prelogging is possible at the current rate of road construction on the North Umpqua. Prelogging is generally done one or more years prior to clearcutting. The two operations are accomplished by separate sale contracts. Because 95 percent of the road mileage on the North Umpqua is constructed by timber purchasers, and because this road mileage is paid for by immediate clearcutting, there is no time between roadbuilding and clearcutting to award and administer a prelogging contract.

Thus, prelogging is projected to begin only after completion of the road system and therefore will begin earlier with the faster roadbuilding plans than with the present plan.

Prelogging is assumed to result in a 5-percent increase in total volume removed from clearcut units. Volume removed by prelogging is assumed to be 8,000 board feet per acre for both timber types. The following tabulation shows regulated and unregulated

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[5] *This figure is an average for all slopes and is based on Umpqua National Forest experience prior to 1966.*

[6] *This acreage is reduced slightly for roads passing through clearcuts.*

[7] *This figure is an average of accumulated mortality (merchantability class 8) for both timber types (Jones and TerBush 1961).*

volumes per acre by type:

	Douglas-fir type (M bd. ft.)	Associated species type (M bd. ft.)
Total volume (regulated if clearcut)	50.22	35.81
Unregulated prelogging (5 percent)	2.511	1.791
Regulated prelogging	5.489	6.209
Clearcut following prelogging	44.731	29.601

As shown above, prelogging and clearcutting are interrelated in terms of volume harvested. They are also interrelated in acreage, because acres prelogged one year are assumed to be clearcut the following year.

CLEARCUTTING

Clearcutting is the primary method of timber harvest on the North Umpqua, accounting for over 90 percent of the total cut in 1966.[8/] Only about 5 percent of clearcutting now occurs in the associated species type, but as the road network is extended, this percentage will increase. This increase is assumed to follow an arithmetic progression from the present level of cutting to a level that will allow the entire type to be harvested every 100 years, the length of the old-growth conversion period.

Another source of interdependency among clearcutting, salvage cutting, and prelogging results from clearing road rights-of-way. If roads are built faster, more timber is clearcut from rights-of-way and less from 50-acre blocks. Less clearcut perimeter is available for salvage, but more roadside acreage can be salvaged.

Because of the interdependency of cutting methods, an iterative procedure is used to calculate annual volumes by type and cutting method for each plan over a 30-year period. This calculation is described in detail in appendix A.

THINNING

Thinning produces only minor benefits for accelerated roadbuilding on the North Umpqua. As of 1966, thinning was planned in stands supporting 30- to 70-year-old timber on slopes less than 37-1/2 percent, or on only 5 percent of total acreage. Primarily because of low average site quality, volumes removable without lowering final harvest volume are quite low. These volumes are unregulated. In accord with the management plan (TerBush and Kampmann 1961), it is assumed that thinning will yield an average of 2,500 board feet per acre for both types, but each acre can be thinned only once during the plan period of 30 years. The only difference among roading plans is earlier recovery of thinning volumes by faster road construction.

8/ The shelterwood system is expected to replace some clearcutting on the North Umpqua in the future. But to simplify calculations, all final harvest (regeneration) cutting projected in this study is assumed to be clearcutting.

SELECTIVE CUTTING

Nearly 45,000 acres of the North Umpqua are designated as landscape management areas or recreation zones. A separately regulated annual cut of 9 million board feet at 5,000 board feet per acre on 1,800 acres is set for these areas. Because this acreage is already accessible, selective cutting in recreation zones has no effect on the rate of roadbuilding.

TOTAL TIMBER VOLUMES

Annual timber volumes by cutting method and timber type are shown for each roadbuilding alternative in appendix B, tables 2 to 6. These data are summarized in figure 1, which shows average annual volume removed for each roading plan. The regulated allowable cut of 201.3 million board feet (including selective cutting) is exceeded by all five plans. As shown by the shape of the curve, the volume of unregulated material increases at a decreasing rate as the rate of road construction increases. The average annual volume for the 450-mile rate is 5.6 percent greater than for the present 75-mile rate.

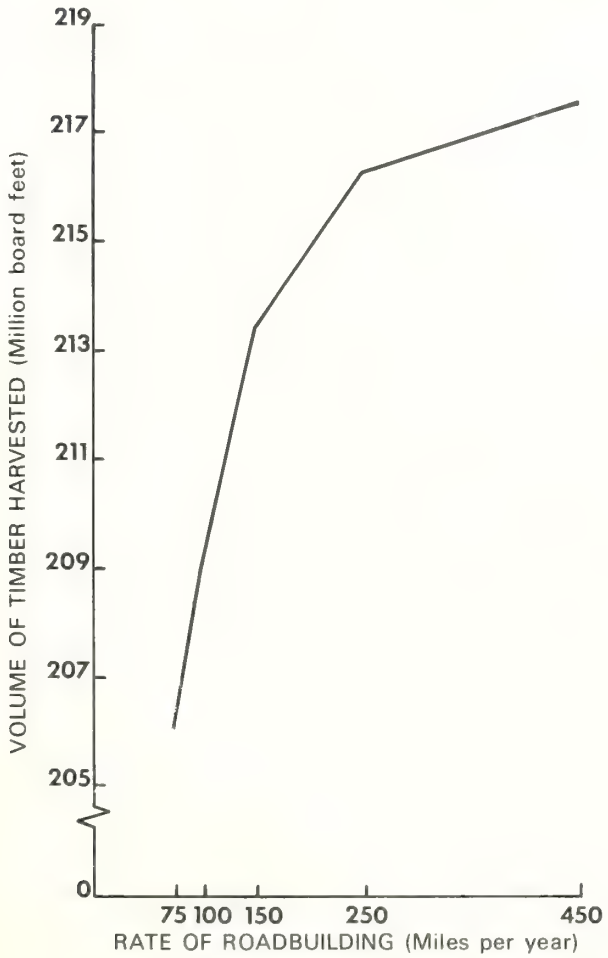

Figure 1.--Average annual volume of timber from 1966 to 1995 for five rates of roadbuilding.

Percentages of average annual volume by cutting method vary among roadbuilding alternatives, as shown in the following tabulation:

Cutting method:	75 miles per year	450 miles per year
Clearcutting	89	66
Salvage cutting	6	18
Thinning	1	1
Selective cutting	4	4
Prelogging	0	11
Total	100	100

These differences are a maximum for the five alternatives. Percent of annual volume by cutting method for the other rates of roadbuilding falls between these two extremes. As shown, increasing the rate of road construction causes a shift from clearcutting to salvage cutting and prelogging.

STUMPAGE PRICES

The following are the stumpage prices assumed in this study for all rates of roadbuilding, every year, in dollars per thousand board feet:

	Douglas-fir type		*Associated species type*	
	Before road completion	After road completion	Before road completion	After road completion
Clearcutting, normal stands	36.71	--	19.37	--
Clearcutting, prelogged stands	--	47.31	--	30.49
Salvage cutting	39.73	40.85	19.29	20.41
Prelogging	--	22.18	--	11.62
Thinning	29.57	35.40	15.49	21.35
Selective cutting	40.85	40.85	20.41	20.41

Multiplying timber volumes by these stumpage prices yields annual benefits for each roadbuilding alternative, as shown in appendix B, table 7.

Prices for clearcutting of normal (not prelogged) stands and for salvage cutting were obtained as an average of actual prices paid for Forest Service timber on the North Umpqua unit during the 2-1/2-year period, January 1964 to June 1966.[9/] Prices paid for thinning volumes are based on data from the Willamette National Forest, located immediately to the north of the Umpqua. Prices for prelogging volumes are based on sales on the Willamette and the Mount Hood (immediately north of the Willamette)

9/ *Pacific Northwest Region, USDA Forest Service, National Forest advertised timber sales, Region 6 (mimeographed report, quarterly).*

National Forests. Prices for selective cutting were assumed equal to salvage cutting prices with the road system completed. The prices for clearcutting of prelogged stands are estimated so that the value of timber removed by clearcutting plus the value of **regulated** prelogging volume equals the value of timber clearcut without prelogging. Consequently, the only benefit of prelogging is the 5-percent volume increase in **unregulated** material valued at the prelogging stumpage price.

Prices shown for the Douglas-fir type are those reported for the Douglas-fir species. An average of all other species prices is shown as the price for the associated species type.

The prices after road completion represent the addition of road development costs to the prices reported before road completion. They are "high bid" prices rather than "statistical high bid" prices. [10/] Forest Service timber is appraised as if access roads are already in place, and bids are received on the same basis. Estimated road construction cost per thousand board feet is then deducted from the high bid price to find the price which the high bidder actually pays. This price is the statistical high bid. When the road system has been completed, there will be no road development costs to subtract. Therefore, present high bid prices are a good estimate of actual prices following road system completion. Until the system is completed, the net payment received by the Forest Service is measured by statistical high bid prices. The increase in stumpage prices received by the Forest Service following road system completion represents the recovery of funds invested in roads.

Present stumpage prices are projected over the 30-year investment period. Because prices are subject to uncertainty, the effects on rates of return of certain price changes are discussed in a sensitivity analysis. These changes include 10- and 20-percent increases and decreases in the prices shown in the above tabulation. Each of these changed price levels is projected over the entire 30-year period.

There are two other types of price changes that might be examined. The first is a change in stumpage prices as the rate of roadbuilding increases. If faster roadbuilding produces more timber and the demand for timber is less than perfectly elastic, the price of timber will tend to fall as the rate of roadbuilding is increased. However, as shown in figure 1, average annual timber volume increased by only 11.5 million board feet or 5.6 percent from the slowest to the fastest roadbuilding alternative. This increase represents only 0.8 percent of the total cut in Douglas County in 1966. The effect on prices of this small increase in volume is believed negligible.

Stumpage prices may change over time even if they do not vary among roadbuilding plans. And they may vary relative to roadbuilding costs. To test the effect of such changes on the relative merit of alternative roading plans, 1- and 3-percent annual increases in stumpage prices, total costs, and both prices and costs together are included in the sensitivity analysis.

[10/] *See footnote 9.*

Cost of Timber Access Roads

The only costs included in the present net worth and related calculations are for construction and maintenance of roads necessary to harvest timber. Additional roading costs to accommodate nontimber traffic or to protect other resources are discussed separately.

The road system to be completed was earlier defined as 2,215 miles, with the only difference among roading plans being the timing of construction of this mileage. Therefore, the only extra costs of accelerated roadbuilding are interest and maintenance from the time roads are completed under an accelerated plan to the time when they would be completed by the present plan. This conclusion assumes that road costs will not change over time from their present level, and that they will not vary with mileage constructed per year. If costs rise in the future, accelerated roadbuilding will lower the initial construction cost relative to the present plan, and vice versa. The effect of such a change is measured by including 1- and 3-percent annual cost increases in the sensitivity analysis. In addition, changes in the level of road costs are examined for their effects on the ranking of roadbuilding alternatives.

An average construction cost of $30,000 per mile is used for all roads. This figure is a weighted average of current (1966) costs for 2.69 miles per section of "U" roads[11] at $39,750 per mile and 1.31 miles per section of temporary roads at $10,000 per mile.[12]

Normal road maintenance costs for the present rate of road construction are accounted for in determining appraised stumpage prices. For the faster rates, road maintenance on the additional mileage is added at $73 per mile per year. Additional mileage is calculated each year as cumulative mileage with accelerated roadbuilding minus cumulative mileage at 75 miles per year. For each alternative, this mileage reaches a maximum in the year the road system is completed and then decreases to zero in the 30th year, when each alternative has completed the same total mileage.

Annual road construction and maintenance costs for each roadbuilding alternative are shown in appendix B, table 8.

EVALUATING ACCELERATED RATES OF ROAD CONSTRUCTION

In a determination of whether roads should be built faster, the relevant benefits and costs are differences between the accelerated rates and the current rate of construction. These are calculated by subtracting current rate values in tables 7 and 8, appendix B, from the respective values for each accelerated rate.

11/ Land use or "U" roads are the lowest standard of Forest Service permanent roads.

12/ Cost data provided by Division of Engineering, Pacific Northwest Region, USDA Forest Service.

Not all of these benefit and cost differences are positive. In fact, cost differences for accelerated roadbuilding plans are negative for all years following projected completion of the road system. This result occurs because the constant annual construction cost of the 75-mile rate is subtracted from costs that are higher during the early years and very low during the later years of the other plans.

Accelerated Roadbuilding for Timber Management Not Economically Justified

Given the previously developed benefits and costs, rates of return on the required additional investments in accelerated roadbuilding are as follows:

Rate of roadbuilding	Rate of return
(Miles per year)	(Percent)
100	3.0
150	3.6
250	3.4
450	2.9

From this listing it can be decided which accelerated rates of roadbuilding would be desirable investments. For example, doubling the rate of construction from the current 75 miles per year to 150 miles per year would be a profitable investment if dollars were available to the Federal Government at a cost of less than 3.6 percent, that is, if the appropriate discount rate were less than 3.6 percent. Unfortunately, the minimum rate that should be considered for federal investments is probably around 5 percent (U.S. Congress, Joint Economic Committee 1968; USDA Forest Service 1969), and about 8 percent may well be a better estimate of the true cost of federal money. In short, at any reasonable discount rate, all of the accelerated roadbuilding alternatives would lose money. This conclusion is illustrated in figure 2: at any discount rate greater than 3.6 percent for any accelerated rate of construction, discounted costs always exceed discounted benefits, and present net worths are negative. Similarly, benefit-cost ratios are less than 1.0; this also indicates that accelerated roadbuilding is a poor investment.

Sensitivity Analyses of Evaluation

To reach this conclusion, a number of specific assumptions were made. Here these assumptions are varied to determine if they are critical to the conclusion.

An important benefit of faster roadbuilding is the earlier removal of both salvable dead timber and current mortality. In 1966, roadside mortality salvage was possible on only 48 acres per mile of road, and the above results are based on this value. By 1971, however, roadside salvage was accomplished on 120 acres per mile, 2-1/2 times the previous amount. Although this change would increase projected average annual timber harvests by from 1 to 4 percent, the effect on the economic desirability of accelerated roadbuilding is negligible: rates of return increase only by about one-tenth of 1 percent for the four accelerated alternatives.

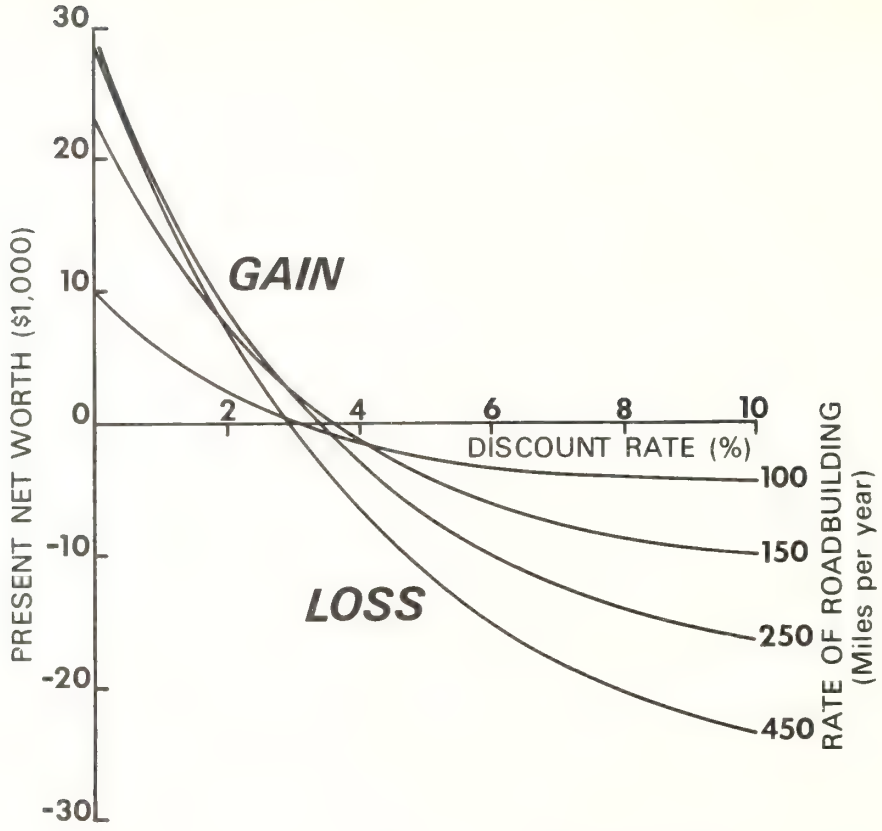

Figure 2.--Present net worth of four accelerated rates of roadbuilding at discount rates from 0 to 10 percent.

The sensitivity of the measures of investment worth was tested for increases and decreases of 10 and 20 percent in the levels of stumpage prices, construction costs, and maintenance costs. Also tested were the effects of 1- and 3-percent annual increases in stumpage prices, total costs, and both prices and costs together. Resulting changes in rates of return are shown in table 1.

A 20-percent increase in the level of stumpage prices or a 20-percent decrease in construction costs raised the rate of return of the 150-mile-per-year alternative to slightly over 4 percent, not a particularly attractive earning rate. Other tested changes in price and cost levels had even less effect.

Annual increases in prices and costs had a substantial effect on the measures of investment worth. Small annual increases in stumpage prices raised the rates of return of the accelerated roadbuilding alternatives by placing a higher value on the additional timber they generate in the first few years of construction. (Only if the rate of price increases exceeded the discount rate would the relatively slow harvesting called for by the present roadbuilding program be favored.) Raising costs over time also increased the desirability of the faster roadbuilding rates relative to the current rate.

Table 1.--Rates of return for four alternative roadbuilding plans for changes in stumpage prices, construction costs, and maintenance costs

Change in			Rate of roadbuilding (miles per year)			
Stumpage prices	Construction costs	Maintenance costs	100	150	250	450
---Percent---			---Percent---			
0	0	0	3.0	3.6	3.4	2.9
+10	0	0	3.3	3.9	3.7	3.2
+20	0	0	3.6	4.2	3.9	3.4
-10	0	0	2.8	3.3	3.1	2.6
-20	0	0	2.6	3.0	2.8	2.4
0	+10	0	2.8	3.4	3.1	2.7
0	+20	0	2.7	3.1	2.9	2.5
0	-10	0	3.3	3.9	3.7	3.2
0	-20	0	3.6	4.3	4.0	3.5
0	0	+10	3.0	3.6	3.4	2.9
0	0	+20	3.0	3.6	3.3	2.9
0	0	-10	3.1	3.6	3.4	2.9
0	0	-20	3.1	3.7	3.4	2.9
+10	+10	+10	3.0	3.6	3.4	2.9
+20	+20	+20	3.0	3.6	3.4	2.9
-10	-10	-10	3.0	3.6	3.4	2.9
-20	-20	-20	3.0	3.6	3.4	2.9
+1/year	0	0	3.7	4.2	3.9	3.4
+3/year	0	0	5.4	5.8	5.2	4.4
0	+1/year	+1/year	3.5	4.0	3.9	3.5
0	+3/year	+3/year	4.6	5.1	5.1	4.9
+1/year	+1/year	+1/year	4.1	4.6	4.4	3.9
+3/year	+3/year	+3/year	6.1	6.7	6.5	6.0

Although higher present net worths, benefit-cost ratios, and rates of return appear to be a paradoxical result of increasing costs, these values are all measured relative to those for the present rate of road construction. If per-mile costs rise as a function of time, the earlier the road system is completed, the less it will cost.

The case in which prices and costs rise at the same rate is particularly important, representing inflation. Combining the separate effects of rising prices and rising costs yields rates of return of up to 6.7 percent.[13/]

[13/] *The propriety of the Federal Government relying on inflation to justify any investments is questioned by McKean (1958).*

Nontimber Benefits and Costs Reduce Desirability of Accelerated Roadbuilding

The preceding section is limited to the economic desirability of accelerated roadbuilding for the management of timber only. Because most nontimber resources lack well-established market prices, their impact on road scheduling decisions is hard to evaluate. Nevertheless, the following tabulation summarizes the expected direction of effect of accelerated roadbuilding on several nontimber resources and activities.

Resource or activity	Probable effect of accelerated roadbuilding
Fisheries	Negative
Soil and water	Negative
Wildlife	Uncertain
Recreation	Uncertain
Fire protection	Uncertain
Administration	Positive

FISHERIES, SOIL, AND WATER RESOURCES ADVERSELY AFFECTED

Accelerated roadbuilding may have damaging effects on fisheries and on soil and water resources unless preventive measures are taken (USDA Forest Service 1969). Increasing annual road construction may increase mass soil movement, erosion, and sediment load in streams. Sediment causes direct injury to fish by abrasion. In addition, it reduces the normal catch of fish by increasing water turbidity, destroys spawning beds by siltation, reduces the amount of available food, and disrupts normal migration of fish.

Although sediment is harmful to fish, most damage can be prevented by known methods of control, such as drainage and filtration, road surface compaction, protection of fill slopes from erosion, and hauling of excess earth away from streams to stable locations. The cost of holding sedimentation to the level experienced at the current rate of roadbuilding in 1966 is one measure of the impact of accelerated roadbuilding. This cost can be expressed per mile of road and included in net worth and earning rate calculations. Doing so will reduce the economic desirability of faster roadbuilding.

If the current level of sedimentation (or any other adverse effect of road construction) is unacceptably high, costs may be further increased, thereby reducing the desirability of accelerated roadbuilding still more. For example, roadbuilding costs on western Oregon National Forests have increased from $30,000 per mile in 1966 to $50,000 to $80,000 per mile in 1971. Much of this increase is for environmental protection. In an extrapolation from table 1, a doubling of construction costs would reduce rates of return for accelerated roadbuilding by one-half to two-thirds. Thus, the desirability of accelerated roadbuilding is drastically reduced when impacts on fisheries, soil, and water resources are considered.

WILDLIFE, RECREATION, FIRE PROTECTION EFFECTS UNCERTAIN

Accelerated roadbuilding may have both positive and negative effects on wildlife and recreation resources and on fire protection. But the overall effect on each is uncertain.

An example of a negative effect on wildlife is the reduction in deer browse associated with the shift away from clearcutting in favor of salvage cutting and prelogging. Although partial cutting opens up the forest canopy and allows more undergrowth to develop, this increase is offset by the reduction in clearcut acreage, since clearcuts provide up to 10 times as much browse per acre as partially cut stands.

The impact of accelerated roadbuilding on recreation may be positive or negative depending on one's point of view. Building roads faster will have beneficial effects for roadside campers and adverse effects for wilderness enthusiasts. Costs to the agency for road and recreation site maintenance may go up as fast as benefits to users. And accelerated roadbuilding may simply shift benefits or costs from one location to another. Because most of the lakes, main streams, and outstanding scenic areas of the North Umpqua are already accessible, net recreation benefits attributable to faster road system completion here should be minor.

Earlier access to timber stands through accelerated road construction would benefit fire suppression efforts. With a completed road system, fires could be extinguished at lower cost and with less loss. However, faster road construction may increase the risk that fires will start. If recreational use is dispersed over a broader area or to less developed sites, the risk of man-caused fires will grow. Thus, protection costs may increase in direct relation to the rate of road construction. Lower suppression cost per fire may be balanced by more fires or by higher prevention costs.

ADMINISTRATIVE COSTS LOWERED

Faster completion of the road system would have definite administrative and management advantages. For example, periodic forest inventories could be accomplished more efficiently. Earlier road construction would allow the forest manager to take advantage of opportunities to harvest high-value species or products as market prices fluctuate. Insect and disease protection and the salvage of catastrophic mortality following windstorms or insect epidemics would also benefit. And it is possible that faster roadbuilding, not tied to timber harvest, would allow a more logical and more efficient scheduling of the construction of various road segments.

CONCLUSIONS

Accelerated roadbuilding does not appear economically justified on the North Umpqua, neither for timber access nor for multiple use management. Although this conclusion is based on conditions as of 1966, changes in harvesting technology, stumpage prices, and roadbuilding costs since that time only strengthen this finding.

The primary timber benefits from accelerated roadbuilding on the North Umpqua

arise from salvage cutting and prelogging. But amounts of salvable dead volume and current mortality per acre are fairly low, even though the forest is overmature, and average site quality is quite low. Higher site forests might be better candidates for accelerated roadbuilding.

The estimated 5-percent increase in volume by prelogging may be conservative for some forest areas. On the other hand, prelogging is possible only where clearcutting is the method of final timber harvest. On forests managed selectively, there is no need nor opportunity for prelogging.

Thinning will be an important benefit of faster roadbuilding on relatively few forests. Generally, young-growth forests where thinning would be practiced already have a road system in place. An exception is young-growth stands established following fires or blowdowns. These areas may benefit from thinning but may not yet be accessible. However, Schallau's (1970) study of young-growth timber on high-site land showed negative rates of return when thinning was the only method of timber harvest.

The major cost of accelerated roadbuilding is interest on the road construction expenditure. Total construction cost in current dollars is identical for the five plans in this study, and differences in maintenance costs are minor. But the interest borne by the fastest roading plan is enormous compared with that for the slowest plan. For even moderate interest rates, this difference overwhelms the relatively modest difference in benefits between these plans.

The findings of this study, coupled with the "Douglas-fir Supply Study" (USDA Forest Service 1969) and Schallau's (1970) study, suggest that accelerated roadbuilding may not be an attractive investment opportunity for National Forests in the Douglas-fir region.

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APPENDIX A

Calculation of Annual Timber Volumes

Clearcutting, salvage cutting, and prelogging are interrelated. Annual volumes of timber removed by each cutting method must be determined simultaneously.

Given factors include the annual allowable cut (regulated cut), annual road mileage constructed by forest type, annual acreage clearcut in the associated species type, and volumes per acre by forest type by all cutting methods.

Calculating volumes harvested by cutting method before the road system is completed (no prelogging) requires the following steps:

1. Calculate volume clearcut from road rights-of-way, by timber type.
   a. Miles of road per year by type (given).
   b. Multiply by 4 acres per mile.
   c. Multiply by volume per acre by type (given).

2. Estimate road mileage passing through clearcut units and therefore not available for salvage.
   a. Estimate total acreage clearcut in blocks.
   b. Divide by 50 acres per block.
   c. Multiply by 0.28 mile of road per block, the distance across a 50-acre square block.

3. Calculate regulated and unregulated roadside salvage volume.
   a. Mileage available (step 1a minus step 2).
   b. Multiply by 48 acres per mile.
   c. Multiply by regulated and unregulated volumes per acre by type (given).

4. Calculate associated species block clearcut volume.
   a. Acreage clearcut in associated species type (given).
   b. Subtract acreage in type clearcut in road right-of-way (step 1b).
   c. Multiply by volume per acre (given).

5. Calculate associated species regulated and unregulated clearcut perimeter salvage volumes.
   a. Multiply acreage clearcut (step 4a) by 0.35 acre of perimeter per acre clearcut.
   b. Multiply by regulated and unregulated volumes per acre (given).

6. Calculate Douglas-fir block clearcut acreage.
   a. Total annual allowable cut (given).
   b. Subtract right-of-way clearcutting (step 1), associated species block clearcutting (step 4), the regulated portions of roadside salvage (step 3), and associated species clearcut perimeter salvage (step 5).
   c. Divide by a weighted average of Douglas-fir clearcut and regulated perimeter salvage volumes per clearcut acre (calculated from given quantities).

7. Compare Douglas-fir block clearcut acreage (step 6) with estimate (step 2a).
   a. If acreages are not equal to the nearest 100 acres, replace estimate (step 2a) with calculated acreage (step 6) and repeat steps 2 through 6.
   b. When acreages are equal continue to step 8.

8. Calculate Douglas-fir block clearcut volume.
   a. Acreage clearcut in blocks (step 6).
   b. Multiply by volume per acre (given).

9. Calculate Douglas-fir clearcut perimeter salvage volume.
   a. Multiply acreage clearcut (step 6) by 0.35 acre of perimeter per clearcut acre.
   b. Multiply by regulated and unregulated volumes per acre (given).

10. Repeat steps 1 through 9 for each year of each plan during which roads are built.

When the road system has been completed, prelogging of clearcut units and resalvage of roadside acreage begin. The following steps are required to calculate volumes harvested by forest type and cutting method:

1. Calculate regulated and unregulated roadside resalvage volume by type.
   a. Total road mileage by type (given).
   b. Multiply by 48 acres per mile.
   c. Subtract acres clearcut in roadside salvage zone. (Average for life of plan is about 10 percent of total acreage.)
   d. Multiply by 10 percent. (Each acre is resalvaged every 10 years.)
   e. Multiply by regulated and unregulated volumes per acre by type (given).

2. Calculate associated species clearcut volume.
   a. Acreage clearcut in associated species type (given).
   b. Multiply by volume per acre (given).

3. Calculate associated species regulated and unregulated clearcut perimeter salvage volumes.
   a. Multiply acreage clearcut (step 2a) by 0.35 acre of perimeter per acre of clearcut.
   b. Multiply by regulated and unregulated volumes per acre (given).

4. Calculate associated species regulated and unregulated prelogging volume.
   a. Acres prelogged are those acres to be clearcut the following year (given).
   b. Multiply by regulated and unregulated volumes per acre (given).

5. Calculate regulated volume to be harvested by clearcutting, salvage cutting, and prelogging in the Douglas-fir type.
   a. Total annual allowable cut (given).
   b. Subtract regulated portion of roadside resalvage (step 1), and associated species clearcutting (step 2), perimeter salvage (step 3), and prelogging (step 4).

6. Allocate regulated Douglas-fir volume to clearcutting, salvage cutting, and prelogging, using the following set of equations:

$$\frac{DVOL_t - (PAC_t)(PVOL/AC)}{CSVOL/AC} = CAC_t$$

$$PAC_t = CAC_{t+1}$$

$$\frac{DVOL_{t+1} - (CAC_{t+1})(CSVOL/AC)}{PVOL/AC} = PAC_{t+1}$$

$$PAC_{t+1} = CAC_{t+2}$$

where:

$DVOL_t$ = Douglas-fir volume cut in year t (step 5).
PAC_t = Acres prelogged in year t (estimated).
$PVOL/AC$ = Regulated prelogging volume per acre.
$CSVOL/AC$ = Weighted average of clearcut volume and regulated perimeter salvage volume per clearcut acre (calculated from given quantities).
CAC_t = Acres clearcut in year t.

   a. Choose PAC_t by iteration such that

$$CAC_{t+1} - CAC_t = CAC_{t+2} - CAC_{t+1}$$

      That is, the difference in clearcut acreage is constant from year to year.

   b. Calculate clearcut volume as acres (from step 6a) times volume per acre (given).
   c. Calculate perimeter salvage volume as acres clearcut (step 6a) times 0.35 acre salvaged times regulated and unregulated volumes per acre (given).
   d. Calculate volume prelogged as acres (from equations of step 6 and step 6a) times regulated and unregulated volumes per acre (given).
   e. Check: The sum of steps 6a, 6b, 6c, and 6d should equal step 5.

7. The difference found in step 6a will be a constant for the remaining years of each plan. Douglas-fir clearcut and prelogged acreage can be calculated by adding this difference to the previous year's total.

8. Repeat steps 1 through 7 for each plan.

APPENDIX B

Tables

Table 2.--Annual timber volumes by cutting method and timber type for roadbuilding at 75 miles per year

(In thousand board feet)

Year	Clearcutting		Salvage		Prelogging		Thinning		Total[1/]		
	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	All
1966	176,793	6,647	10,884	612	0	0	2,308	1,025	194,985	12,284	207,269
1967	175,848	7,586	10,599	906	0	0	2,308	1,025	193,755	13,517	207,272
1968	174,912	8,516	10,314	1,197	0	0	2,308	1,025	192,534	14,738	207,272
1969	173,967	9,455	10,167	1,353	0	0	2,308	1,025	191,442	15,833	207,275
1970	173,023	10,394	9,822	1,644	0	0	2,308	1,025	190,153	17,063	207,216
1971	172,087	11,324	9,600	1,935	0	0	2,308	1,025	188,995	18,284	207,279
1972	171,142	12,263	9,315	2,226	0	0	2,308	1,025	187,765	19,514	207,279
1973	170,207	13,193	9,030	2,520	0	0	2,308	1,025	186,545	20,738	207,283
1974	169,261	14,132	8,886	2,673	0	0	2,308	1,025	185,455	21,830	207,285
1975	168,325	15,062	8,601	2,964	0	0	2,308	1,025	184,234	23,051	207,285
1976	167,380	16,001	8,316	3,258	0	0	568	932	181,264	24,191	205,455
1977	166,445	16,931	8,028	3,552	0	0	568	932	180,041	25,415	205,456
1978	165,500	17,870	7,746	3,840	0	0	568	932	178,814	26,642	205,456
1979	164,564	18,800	7,461	4,134	0	0	568	932	177,593	27,866	205,459
1980	163,619	19,739	7,317	4,287	0	0	568	932	176,504	28,958	205,462
1981	162,683	20,669	7,032	4,578	0	0	568	932	175,283	30,179	205,462
1982	161,738	21,608	6,747	4,872	0	0	568	932	174,053	31,412	205,465
1983	160,802	22,538	6,465	5,160	0	0	568	932	172,835	32,630	205,465
1984	159,857	23,478	6,177	5,457	0	0	568	932	171,602	33,867	205,469
1985	158,922	24,407	6,033	5,607	0	0	568	932	170,523	34,946	205,469
1986	157,977	25,346	5,748	5,901	0	0	568	932	169,293	36,179	205,472
1987	157,041	26,276	5,463	6,192	0	0	568	932	168,072	37,400	205,472
1988	156,096	27,215	5,178	6,486	0	0	568	932	166,842	38,633	205,475
1989	155,159	28,146	4,893	6,777	0	0	568	932	165,620	39,855	205,475
1990	154,215	29,084	4,749	6,930	0	0	568	932	164,532	40,946	205,478
1991	153,280	30,014	4,323	7,362	0	0	568	932	163,171	42,308	205,479
1992	152,335	30,953	4,179	7,512	0	0	568	932	162,082	43,397	205,479
1993	151,389	31,893	3,894	7,806	0	0	568	932	160,851	44,631	205,482
1994	150,454	32,822	3,612	8,097	0	0	568	932	159,634	45,851	205,485
1995	149,508	33,762	3,360	8,358	0	0	568	932	158,436	47,052	205,488

[1/] Includes 5 million board feet in Douglas-fir and 4 million board feet in associated species from selected cutting.

Table 3.--Annual timber volumes by cutting method and timber type for roadbuilding at 100 miles per year

(In thousand board feet)

Year	Clearcutting		Salvage		Prelogging		Thinning		Total[1/]		
	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	All
1966	174,164	6,625	14,046	888	0	0	2,510	1,355	195,720	12,868	208,588
1967	173,227	7,556	13,623	1,320	0	0	2,510	1,355	194,360	14,231	208,591
1968	172,291	8,487	13,200	1,752	0	0	2,510	1,355	193,001	15,594	208,595
1969	171,354	9,418	12,621	2,340	0	0	2,510	1,355	191,485	17,113	208,598
1970	170,418	10,349	12,192	2,775	0	0	2,510	1,355	190,120	18,479	208,599
1971	169,469	11,280	11,769	3,204	0	0	2,510	1,355	188,748	19,839	208,587
1972	168,543	12,211	11,346	3,636	0	0	2,510	1,355	187,399	21,202	208,601
1973	167,607	13,142	10,905	4,083	0	0	2,510	1,355	186,022	22,580	208,602
1974	166,669	14,073	10,341	4,656	0	0	2,510	1,355	184,520	24,084	208,604
1975	165,732	15,004	9,918	5,088	0	0	2,510	1,355	183,160	25,447	208,607
1976	164,795	15,935	9,492	5,523	0	0	770	1,263	180,057	26,721	206,778
1977	163,858	16,867	9,051	5,967	0	0	770	1,263	178,679	28,097	206,776
1978	162,920	17,798	8,628	6,399	0	0	770	1,263	177,318	29,460	206,778
1979	161,983	18,729	8,064	6,972	0	0	770	1,263	175,817	30,964	206,781
1980	161,047	19,660	7,641	7,404	0	0	770	1,263	174,458	32,327	206,785
1981	160,109	20,591	7,200	7,851	0	0	770	1,263	173,079	33,705	206,784
1982	159,172	21,522	6,777	8,283	0	0	770	1,263	171,719	35,068	206,787
1983	158,236	22,453	6,351	8,715	0	0	770	1,263	170,357	36,431	206,788
1984	157,299	23,384	5,772	9,303	0	0	770	1,263	168,841	37,950	206,791
1985	156,361	24,315	5,349	9,735	0	0	770	1,263	167,480	39,313	206,793
1986	155,425	25,246	4,923	10,167	0	0	770	1,263	166,118	40,676	206,794
1987	154,488	26,177	4,500	10,599	0	0	770	1,263	164,758	42,039	206,797
1988	125,947	27,108	3,171	2,247	21,501	6,264	108	177	155,727	39,796	195,523
1989	120,219	23,178	25,610	9,771	21,352	6,472	0	0	172,181	43,421	215,602
1990	119,385	23,947	25,591	9,798	21,202	6,680	0	0	171,178	44,425	215,603
1991	118,550	24,717	25,571	9,825	21,053	6,888	0	0	170,174	45,430	215,604
1992	117,715	25,486	25,552	9,852	20,904	7,096	0	0	169,171	46,434	215,605
1993	116,881	26,256	25,532	9,879	20,754	7,304	0	0	168,167	47,439	215,606
1994	116,046	27,026	25,512	9,909	20,605	7,512	0	0	167,163	48,447	215,610
1995	115,211	27,795	25,492	9,936	20,456	7,720	0	0	166,159	49,451	215,610

[1/] Includes 5 million board feet in Douglas-fir and 4 million board feet in associated species from selected cutting.

Table 4.--Annual timber volumes by cutting method and timber type for roadbuilding at 150 miles per year

(In thousand board feet)

Year	Clearcutting		Salvage		Prelogging		Thinning		Total[1/]		
	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	All
1966	168,755	6,624	20,436	1,521	0	0	2,895	1,985	197,086	14,130	211,216
1967	167,817	7,556	19,479	2,484	0	0	2,895	1,985	195,191	16,025	211,216
1968	166,880	8,487	18,528	3,444	0	0	2,895	1,985	193,303	17,916	211,219
1969	165,943	9,418	17,445	4,533	0	0	2,895	1,985	191,283	19,936	211,219
1970	165,005	10,349	16,479	5,511	0	0	2,895	1,985	189,379	21,845	211,224
1971	164,069	11,280	15,522	6,474	0	0	2,895	1,985	187,486	23,739	211,225
1972	163,132	12,211	14,565	7,437	0	0	2,895	1,985	185,592	25,633	211,225
1973	162,195	13,142	13,596	8,412	0	0	2,895	1,985	183,686	27,539	211,225
1974	161,258	14,073	12,489	9,528	0	0	2,895	1,985	181,642	29,586	211,228
1975	160,321	15,004	11,532	10,494	0	0	2,895	1,985	179,748	31,483	211,231
1976	159,384	15,935	10,566	11,469	0	0	1,155	1,893	176,101	33,297	209,402
1977	158,446	16,867	9,594	12,447	0	0	1,155	1,893	174,195	35,207	209,402
1978	157,510	17,798	8,625	13,425	0	0	1,155	1,893	172,290	37,116	209,406
1979	156,572	18,729	7,503	14,553	0	0	885	1,453	169,960	38,735	208,695
1980	140,075	19,660	5,025	12,456	22,624	4,600	0	0	172,724	40,716	213,440
1981	126,501	17,021	26,144	9,705	22,475	4,808	0	0	180,120	35,534	213,654
1982	126,668	17,790	26,124	9,732	22,327	5,016	0	0	180,119	36,538	216,657
1983	124,835	18,560	26,105	9,759	22,177	5,224	0	0	178,117	37,543	215,660
1984	124,001	19,329	26,085	9,789	22,028	5,432	0	0	177,114	38,550	215,664
1985	123,168	20,099	26,066	9,816	21,879	5,640	0	0	176,113	39,555	215,668
1986	122,335	20,869	26,046	9,843	21,731	5,848	0	0	175,112	40,560	215,672
1987	121,501	21,638	26,027	9,870	21,581	6,056	0	0	174,109	41,564	215,673
1988	120,668	22,408	26,007	9,897	21,432	6,264	0	0	173,107	42,569	215,676
1989	119,835	23,178	25,988	9,924	21,283	6,472	0	0	172,106	43,574	215,680
1990	119,001	23,947	25,969	9,951	21,134	6,680	0	0	171,104	44,578	215,682
1991	118,168	24,717	25,949	9,978	20,985	6,888	0	0	170,102	45,583	215,685
1992	117,335	25,486	25,930	10,005	20,836	7,096	0	0	169,101	46,587	215,688
1993	116,501	26,256	25,910	10,032	20,687	7,304	0	0	168,098	47,592	215,690
1994	115,668	27,026	25,890	10,062	20,538	7,512	0	0	167,096	48,600	215,696
1995	114,835	27,795	25,871	10,089	20,389	7,720	0	0	166,095	49,604	215,699

[1/] Includes 5 million board feet in Douglas-fir and 4 million board feet in associated species from selected cutting.

Table 5.--Annual timber volumes by cutting method and timber type for roadbuilding at 250 miles per year

(In thousand board feet)

Year	Clearcutting		Salvage		Prelogging		Thinning		Total[1/]		
	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	All
1966	160,275	4,297	31,659	4,320	0	0	3,662	3,520	200,596	16,137	216,733
1967	157,680	6,876	29,088	6,912	0	0	3,662	3,520	195,430	21,308	216,738
1968	155,085	9,454	26,517	9,504	0	0	3,662	3,520	190,264	26,478	216,742
1969	152,347	12,175	23,805	12,240	0	0	3,662	3,520	184,814	31,935	216,749
1970	149,752	14,754	21,234	14,832	0	0	3,662	3,520	179,648	37,106	216,754
1971	147,157	17,332	18,663	17,424	0	0	3,662	3,520	174,482	42,276	216,758
1972	144,418	20,054	15,948	20,160	0	0	3,662	3,520	169,028	47,734	216,762
1973	141,823	22,632	13,380	22,752	0	0	3,662	3,520	163,865	52,904	216,769
1974	125,588	23,348	12,576	18,684	22,006	5,376	3,395	2,805	168,565	54,213	222,778
1975	123,047	19,892	26,412	9,942	21,892	5,536	1,740	92	178,091	39,462	217,553
1976	122,406	20,484	26,397	9,963	21,777	5,696	0	0	175,580	40,143	215,723
1977	121,764	21,076	26,382	9,984	21,662	5,856	0	0	174,808	40,916	215,724
1978	121,123	21,668	26,367	10,005	21,547	6,016	0	0	174,037	41,689	215,726
1979	120,482	22,260	26,352	10,026	21,433	6,176	0	0	173,267	42,462	215,729
1980	119,840	22,852	26,331	10,047	21,318	6,336	0	0	172,489	42,435	214,924
1981	119,199	23,444	26,322	10,068	21,203	6,496	0	0	171,724	44,008	215,732
1982	118,557	24,036	26,307	10,089	21,089	6,656	0	0	170,953	44,781	215,734
1983	117,916	24,628	26,292	10,110	20,974	6,816	0	0	170,182	45,554	215,736
1984	117,274	25,220	26,277	10,131	20,859	6,976	0	0	169,410	46,327	215,737
1985	116,633	25,812	26,262	10,152	20,744	7,136	0	0	168,639	47,100	215,739
1986	115,992	26,404	26,247	10,173	20,630	7,296	0	0	167,869	47,873	215,742
1987	115,350	26,996	26,232	10,194	20,515	7,456	0	0	167,097	48,646	215,743
1988	114,709	27,588	26,217	10,215	20,400	7,616	0	0	166,326	49,419	215,745
1989	114,067	28,180	26,202	10,236	20,286	7,776	0	0	165,555	50,192	215,747
1990	113,426	28,772	26,187	10,257	20,171	7,936	0	0	164,784	50,965	215,749
1991	112,784	29,364	26,169	10,278	20,056	8,096	0	0	164,009	51,738	215,747
1992	112,143	29,956	26,154	10,299	19,941	8,256	0	0	163,238	52,511	215,749
1993	111,501	30,548	26,139	10,320	19,827	8,416	0	0	162,467	53,284	215,751
1994	110,860	31,140	26,124	10,341	19,712	8,576	0	0	161,696	54,057	215,753
1995	110,219	31,732	26,109	10,362	19,597	8,736	0	0	160,925	54,830	215,755

[1/] Includes 5 million board feet in Douglas-fir and 4 million board feet in associated species from selected cutting.

Table 6.--Annual timber volumes by cutting method and timber type for roadbuilding at 450 miles per year

(In thousand board feet)

Year	Clearcutting		Salvage		Prelogging		Thinning		Total[1/]		
	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	All
1966	132,211	10,027	54,879	10,080	0	0	5,203	5,772	197,293	29,879	227,172
1967	123,850	18,335	46,596	18,432	0	0	5,203	5,772	180,649	46,539	227,188
1968	115,345	26,786	38,172	26,928	0	0	5,203	5,772	163,720	63,486	227,206
1969	106,840	35,237	29,745	35,424	0	0	5,203	5,772	146,788	80,433	227,221
1970	109,919	35,810	24,429	36,000	0	0	4,932	5,330	144,280	81,140	225,420
1971	116,140	36,204	16,216	6,476	21,776	8,168	1,740	92	160,872	54,940	215,812
1972	121,755	30,223	16,646	6,487	21,713	8,256	1,740	92	166,854	49,058	215,912
1973	121,408	30,548	16,638	6,499	21,651	8,336	1,740	92	166,437	49,475	215,912
1974	121,079	30,844	16,630	6,509	21,592	8,424	1,740	92	166,041	49,869	215,910
1975	120,732	31,170	16,622	6,521	21,530	8,504	1,740	92	165,624	50,287	215,911
1976	111,065	31,466	25,587	10,140	19,801	8,592	0	0	161,453	54,198	215,651
1977	110,717	31,791	25,579	10,152	19,740	8,672	0	0	161,036	54,615	215,651
1978	110,394	32,087	25,571	10,161	19,677	8,760	0	0	160,642	55,008	215,650
1979	110,041	32,413	25,562	10,174	19,615	8,848	0	0	160,218	55,435	215,653
1980	109,693	32,739	25,554	10,185	19,552	8,928	0	0	159,799	55,852	215,651
1981	109,368	33,035	25,546	10,196	19,490	9,016	0	0	159,404	56,247	215,651
1982	109,022	33,360	25,538	10,207	19,428	9,096	0	0	158,988	56,663	215,651
1983	108,699	33,656	25,530	10,218	19,365	9,184	0	0	158,594	57,058	215,652
1984	108,350	33,982	25,522	10,230	19,304	9,264	0	0	158,176	57,476	215,652
1985	108,027	34,278	25,514	10,240	19,241	9,352	0	0	157,782	57,870	215,652
1986	107,680	34,604	25,505	10,251	19,179	9,432	0	0	157,364	58,287	215,651
1987	107,355	34,900	25,497	10,262	19,117	9,520	0	0	156,969	58,682	215,651
1988	107,008	35,225	25,489	10,273	19,055	9,600	0	0	156,552	59,098	215,650
1989	106,686	35,521	25,481	10,284	18,992	9,688	0	0	156,159	59,493	215,652
1990	106,332	35,847	25,473	10,296	18,930	9,776	0	0	155,735	59,919	215,654
1991	105,984	36,172	25,465	10,307	18,868	9,856	0	0	155,317	60,335	215,652
1992	105,661	36,468	25,456	10,318	18,806	9,944	0	0	154,923	60,730	215,653
1993	105,313	36,794	25,448	10,329	18,743	10,024	0	0	154,504	61,147	215,651
1994	104,989	37,090	25,440	10,340	18,682	10,112	0	0	154,111	61,542	215,653
1995	104,641	37,416	25,432	10,351	18,619	10,192	0	0	153,692	61,959	215,651

[1/] Includes 5 million board feet in Douglas-fir and 4 million board feet in associated species from selected cutting.

Table 7.--Annual dollar benefits from timber harvest for five alternative roadbuilding plans

(In thousand dollars)

Year	Rate of roadbuilding (miles per year)				
	75	100	150	250	450
1966	7,433	7,478	7,567	7,753	7,952
1967	7,411	7,453	7,531	7,655	7,638
1968	7,389	7,429	7,495	7,558	7,318
1969	7,370	7,401	7,457	7,455	6,999
1970	7,347	7,376	7,421	7,357	6,908
1971	7,325	7,350	7,385	7,260	8,310
1972	7,303	7,326	7,349	7,157	8,358
1973	7,281	7,301	7,313	7,060	8,351
1974	7,262	7,273	7,275	6,903	8,344
1975	7,240	7,248	7,236	8,598	8,337
1976	7,165	7,170	7,150	8,532	8,291
1977	7,143	7,145	7,114	8.519	8,284
1978	7,121	7,120	7,078	8,506	8,277
1979	7,099	7,092	7,039	8,493	8,270
1980	7,079	7,067	6,853	8,479	8,263
1981	7,057	7,042	8,610	8,467	8,256
1982	7,035	7,017	8,593	8,453	8,249
1983	7,013	6,992	8,576	8,440	8,242
1984	6,991	6,964	8,559	8,427	8,235
1985	6,972	6,940	8,542	8,414	8,228
1986	6,950	6,915	8,525	8,401	8,221
1987	6,928	6,890	8,508	8,388	8,215
1988	6,905	6,159	8,490	8,374	8,208
1989	6,883	8,475	8,473	8,361	8,201
1990	6,864	8,457	8,456	8,348	8,194
1991	6,839	8,440	8,439	8,335	8,187
1992	6,820	8,423	8,422	8,322	8,180
1993	6,798	8,406	8,405	8.308	8.173
1994	6,776	8,389	8,388	8,295	8,166
1995	6,754	8,372	8,371	8,282	8,159

Table 8.--Annual road construction and maintenance cost for five alternative roadbuilding plans

(In thousand dollars)

Year	Rate of roadbuilding (miles per year)				
	75	100	150	250	450
1966	2,250	3,002	4,505	7,513	13,527
1967	2,250	3,004	4,511	7,526	13,555
1968	2,250	3,005	4,516	7,538	13,582
1969	2,250	3,007	4,522	7,551	13,610
1970	2,250	3,009	4,527	7,564	12,584
1971	2,250	3,011	4,533	7,577	129
1972	2,250	3,013	4,538	7,589	123
1973	2,250	3,015	4,544	7,602	118
1974	2,250	3,016	4,549	6,562	112
1975	2,250	3,018	4,555	107	107
1976	2,250	3,020	4,560	101	101
1977	2,250	3,022	4,566	96	96
1978	2,250	3,024	4,571	91	91
1979	2,250	3,026	4,577	85	85
1980	2,250	3,027	3,530	80	80
1981	2,250	3,029	74	74	74
1982	2,250	3,031	69	69	69
1983	2,250	3,033	63	63	63
1984	2,250	3,035	58	58	58
1985	2,250	3,037	52	52	52
1986	2,250	3,038	47	47	47
1987	2,250	3,040	41	41	41
1988	2,250	486	36	36	36
1989	2,250	30	30	30	30
1990	2,250	25	25	25	25
1991	2,250	19	19	19	19
1992	2,250	14	14	14	14
1993	2,250	8	8	8	8
1994	2,250	3	3	3	3
1995	1,200	0	0	0	0

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Payne, Brian R.
1972. Accelerated roadbuilding on the North Umpqua--an economic analysis. USDA Forest Serv. Res. Pap. PNW-137, 32 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Accelerated construction of roads for access to old-growth timber on a unit of the Umpqua National Forest in Oregon was found economically undesirable, using the then-current (1966) roadbuilding rate.

Keywords: Forest roads, forestry economics, logging.

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Payne, Brian R.
1972. Accelerated roadbuilding on the North Umpqua--an economic analysis. USDA Forest Serv. Res. Pap. PNW-137, 32 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Accelerated construction of roads for access to old-growth timber on a unit of the Umpqua National Forest in Oregon was found economically undesirable, using the then-current (1966) roadbuilding rate.

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A METHOD OF ESTIMATING LOG WEIGHTS

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SYMBOLS

d_1	Actual small end diameter inside bark - inches
d_2	Actual large end diameter outside bark - inches
d_1'	Small end scaling diameter inside bark - inches
DI	Density index - pounds per cubic foot
L	Actual length - feet
L'	Scaling length - feet ($L = L'$ + trim allowance)
n	Number of truckloads in the sample for the density index
V_B	Scribner log volume - board feet
	Cubic log volume inside bark - cubic feet
	Estimated cubic volume outside bark - cubic feet
W	Actual log weight - pounds
$\hat{W}$	Estimated log weight - pounds

ABSTRACT

This paper presents a practical method of estimating the weights of logs before they are yarded. Knowledge of log weights is required to achieve optimum loading of modern yarding equipment. Truckloads of logs are weighed and measured to obtain a local density index (pounds per cubic foot) for a species of logs. The density index is then used to estimate the weights of remaining logs before they are yarded. Estimates are made directly from graphs, tables, or a slide rule.

KEYWORDS: Logs, weights, logging.

1.0 INTRODUCTION

The forest industry has long recognized the need for a practical method of estimating the weight of logs before they are yarded. This need has accelerated as aerial logging systems having critical weight limitations find wider application. Analytical techniques which provide payload capabilities for these yarding systems are now available. Log weight estimates are needed for optimum utilization without overloads.

This paper presents a method of estimating log weights by use of a factor called a density index. Before log weights are estimated, the local density index for a species of logs is found by measuring and weighing truckloads of these logs. The density index, found in this manner, is used to estimate the remaining logs of the same species before they are yarded. Graphs and tables for estimating log weights are given as well as the mathematics for a slide rule.

This practical method of estimating log weights should be of interest to all concerned with the operation of weight-sensitive timber harvesting equipment.

2.0 BACKGROUND

A cooperative study[1/] with the University of Washington's College of Forestry was performed to obtain some insight into the variations in log density. This study analyzed logs of several species from locations in Alaska and Washington. Analysis showed that the ratio of weight to cubic log volume has a much smaller variation than the ratio of weight to board-foot volume, and the study recommended that further efforts be directed toward a method of weight estimation based on cubic volume. Appendix I discusses the board-foot to cubic-foot ratio as a function of log size.

3.0 ANALYTICAL APPROACH

In order to devise a practical method of estimating log weights, several assumptions were made. These are listed below:

1. Reasonably accurate cubic volumes of logs can be obtained from the scaling length, the large end diameter outside bark, and an assumed taper.
2. A sample of log cubic volumes and weights can provide a measure of the green density (density index) which can then be used to estimate log weights.
3. The green density of logs is reasonably constant for a given species and location.
4. Gradual changes in the green density due to location and seasonal variations can be determined by a moving average of the density index.

[1/] *K. J. Turnbull, L. V. Pienaar, and I. E. Bella. Report on a study of log weight estimation. (Unpublished paper on file at Pac. Northwest Forest & Range Exp. Stn., Seattle, Wash.)*

5. Volumetric errors, due to differences between actual scaling lengths and between actual and assumed taper, can be considered compensating in that the error is contained in both the sample of logs used to determine the average density value and in logs for which an estimate of weight is desired.

These assumptions ignore minor variations which are known to occur so as to allow formulation of a practical method of estimating log weights. Diameters are measured outside the bark to account for volume of the bark and to include variations in bark thickness.

There are variations in taper from tree to tree and from log to log in the same tree which can cause errors in cubic volume estimates. A method of estimating cubic volumes from the length and the sum of the end diameters has been suggested. While this method may yield more accurate cubic volume estimates, it cannot be directly applied to the critical problem of determining the length to buck a log for a given weight. The bucker generally knows the large end diameter since logs are cut from the butt end to maximize value. With a system based on the sum of the diameters, the bucker is left with two unknowns at this point: the length and the small end diameter. This method, based on large end diameter with an assumed taper, provides the bucker with a direct means of determining the length to be cut for a given log weight.

Cubic volume approximations and variations inherent in green density cause differences between actual and estimated log weights. For a yarding system that has little or no tolerance for overloads, estimates of log weights must be below specified capacity to reduce the probability of overloads. For example, assume the difference between estimated and actual weights for individual logs has a standard deviation of 12 percent of the actual weight. A reduction in capacity of 10 percent for estimating the weight of single log loads would result in the probability that about one load in five is over capacity. A reduction of 20 percent would result in less than one load in 20 being over capacity.

The mathematics of this method follow from the assumptions listed. From a sample of logs, a density index is found by taking the ratio of log weight to cubic volume. If truckloads of logs are used, the procedure given in Section 4.1 consists of finding a density index for each load,

$$DI = \frac{\Sigma W}{\Sigma \hat{V}_C},$$

(see the list of symbols, inside front cover, for the meaning of these and other symbols) in the sample and then obtaining an average of the density indexes,

$$DI = \frac{DI_1 + DI_2 + DI_3 + \ldots + DI_n}{n}.$$

The cubic volumes for the sampled logs can be obtained from tables 1 and 2 (Appendix II). These cubic volumes are based on the formula,

$$V_C = \frac{\pi}{576} \left(d_2 - \frac{L}{16}\right)^2 L,$$

which assumes a taper of 1 inch per 8 feet of length. In the calculation of the values listed in the table, a trim allowance of 1 inch per 4 feet of length was added to the scaling lengths.

Applying the density index in order to estimate log weights can be considered the reverse of obtaining the density index. Namely, log measurements are used to obtain the cubic volume which is then multiplied by the density index to estimate the log weight. That is,

$$\hat{W} = (DI)\ \hat{V}_C\ .$$

In practice, the user need not be concerned with cubic volumes. Tables, graphs, and the mathematics of a slide rule have been provided so that a weight estimate can be obtained directly from the density index, the large end diameter, and the scaling length. Both the curves and the tables for log weights in Appendix II are based on the same equation as used previously for the cubic volumes.

An alternate method of estimating log weights can be provided by a slide rule. This requires that the previous expression be transformed into a form similar to

$$\log\ (\frac{\hat{W} \cdot 576}{\pi}) = \log\ (DI) + \log\ (d_2 - \frac{L}{16})^2 + \log\ (L).$$

However, the above equation is not satisfactory for a slide rule because the variable (L) appears in the logarithm of two terms. The ($d_2 - L/16$) term can be approximated by ($d_2 - 2$) for lengths up to 40 feet. This corresponds to a length of 32 feet. If logs weighing 10,000 pounds with a density index of 50 are considered, this approximation results in estimates that are about 4 percent low for a length of 10 feet and about 4 percent high for a length of 40 feet. These percentages will be larger for lighter logs and smaller for heavier logs. For lengths beyond 40 feet, the error introduced by the approximation becomes large. To avoid excessive errors, lengths for the slide rule beyond 40 feet can be obtained from the graph for a density index of 50 and a log weight of 10,000 pounds. Figure 1 shows a slide rule for estimating log weights.

4.0 SUGGESTED PROCEDURE

The following is a suggested procedure to obtain log weight estimates. The procedure consists of determining a density index for each species and location by sampling logs. Once the density index has been determined, the weight of logs can be estimated.

4.1 Sampling for the Density Index

The density index is found from an initial sample of log weights and dimensions. Truckloads of logs are convenient units to obtain these data. The

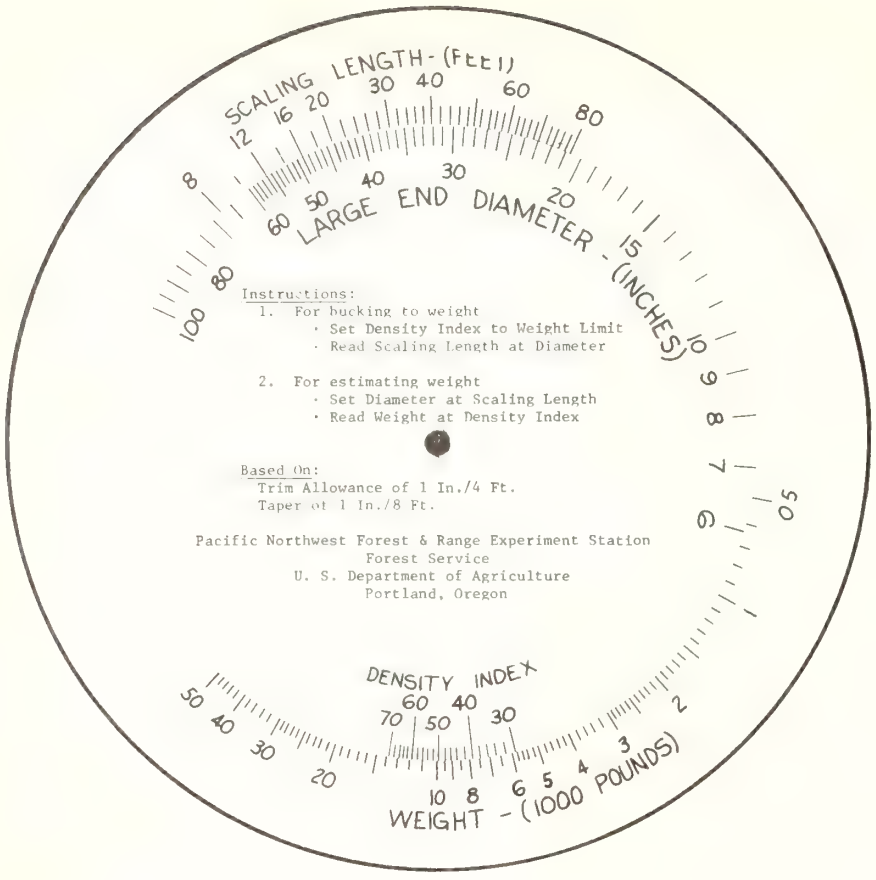

SCALING LENGTH - (Feet)
LARGE END DIAMETER - (INCHES)
Instructions:
1. For bucking to weight
· Set Density Index to Weight Limit
· Read Scaling Length at Diameter
2. For estimating weight
· Set Diameter at Scaling Length
· Read Weight at Density Index
Based On:
Trim Allowance of 1 In./4 Ft.
Taper of 1 In./8 Ft.
Pacific Northwest Forest & Range Experiment Station
Forest Service
U. S. Department of Agriculture
Portland, Oregon
DENSITY INDEX
WEIGHT - (1000 POUNDS)

Figure 1.—Slide rule for estimating log weights.

density index can be obtained from other sources such as individual log weights and measurements or knowledge from previous nearby logging operations. Four or five truckloads or their equivalent in individual logs should generally be sufficient for a reasonably accurate density index.

To compute a density index for a truckload of logs, the net log weight and cubic volumes must be determined. Scaled cubic volumes are obtained from the large end diameter outside bark and the scaling length by referring to tables 1 and 2 of Appendix II. A worksheet is given in figure 26 of appendix II to facilitate the determination of density index of a truckload of logs. An average of the density indexes of several truckloads provides the density index for estimating log weights.

A moving average can incorporate density changes due to time, dependent influences such as seasonal variations, and gradual changes in location. A moving average is constructed by periodically obtaining a new sample for incorporation in the average density index and eliminating the oldest sample. An example of a four-load moving average of density index is shown in figure 2. A worksheet (fig. 27) is provided in Appendix II.

4.2 Estimating Log Weights

Once a density index has been established for a particular location and species, the weights of logs can be estimated from the graphs or tables in

Figure 2.—Example of moving average of density index.

Four-load moving average

Logging site: *Paddle Creek* Species: *Douglas-fir*

Sample number	Date of sample	Sample density index	Moving total of density index[1/]	Current moving average[2/]
1	Jan. 2	45.2		
2	Jan. 2	51.2		
3	Jan. 2	40.1		
4	Jan. 3	49.7	186.2	46.6
5	Mar. 2	42.0	183.0	45.8
6	May 3	43.5	175.3	43.8
7	July 1	41.7	176.9	44.2
8	Sept. 2	52.8	180.0	45.0
9	Nov. 2	44.5	182.5	45.6

[1/] Add newest sample and delete oldest sample which was included in previous total.

[2/] Divide moving total by number of samples in moving average.

Appendix II, or from a slide rule. Each of the graphs and tables in Appendix II is for a specific density index. A range of density indexes from 30 to 70 pounds per cubic foot is included. The nearest density index established by sampling is used for estimating log weights.

Two different problems are encountered when attempting to determine capacity loads for yarding equipment. In large diameter timber, single logs may make up the majority of loads and each log must be sized to approach the weight limit of the equipment. In smaller diameter timber, an estimate of the weight of each log is necessary to combine a number of logs into a capacity load. The graphs are arranged for the solution of either problem. When the size of a single log must be found to approach a capacity limit, the graph nearest the required density index is entered along the bottom with the large end diameter. A line is followed up to the appropriate log weight and then over to the log scaling length. When estimates of log weights are required, the graph is entered along the bottom with the large end diameter, and the line is followed upward until the proper length is reached, and the weight is read. Large end diameters should be measured outside the bark and lengths should be those defined by local custom or contract. The tables are used in a similar manner. For a single log load, the large end diameter is located in the table. The indicated

row is followed until the weight at or just below the limit is found. Bucking length is then obtained from the top of the table. For a multilog load, the weight estimate of each log is found directly from the large end diameter and scaling length.

Butt logs must be treated somewhat differently from other logs because of the concave exterior surface due to the root swell. Probably the best way to handle these logs is to make an estimate of the large end diameter outside the bark as though the taper of the log continued through to the end, disregarding the swell, as shown in figure 3.

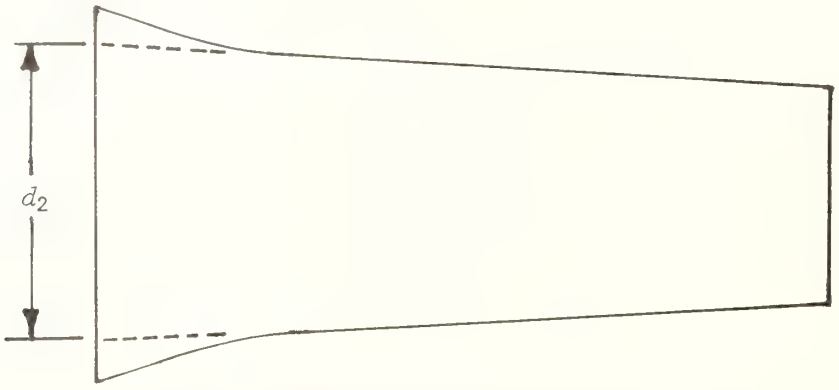


Figure 3.—Estimating large end diameter (d_2) on butt log.

APPENDIX I

THE BOARD-FOOT TO CUBIC-FOOT RATIO

Log weight estimates are commonly obtained by multiplying the board-foot scale of a log by a constant. The particular constant usually depends on the species of the log and the experience of the estimator. Use of the board-foot scale as a basis for weight estimates is due primarily to the logger's familiarity with that system of measurement. Unfortunately, the board-foot scale is only an estimate of the lumber yield of a log rather than a measure of its wood content.

Figure 4 shows the relationships between the board-foot to cubic-foot ratio and the cubic volume of logs for various diameters and lengths. The ratio can be considered a measure of the amount of total wood content which is included in the board-foot scale (if all the wood was included, the ratio would be a constant 12). The plot is of interest to the problem of log weight estimation because it clearly shows the wide variation of the board-foot to cubic-foot ratio with log size.

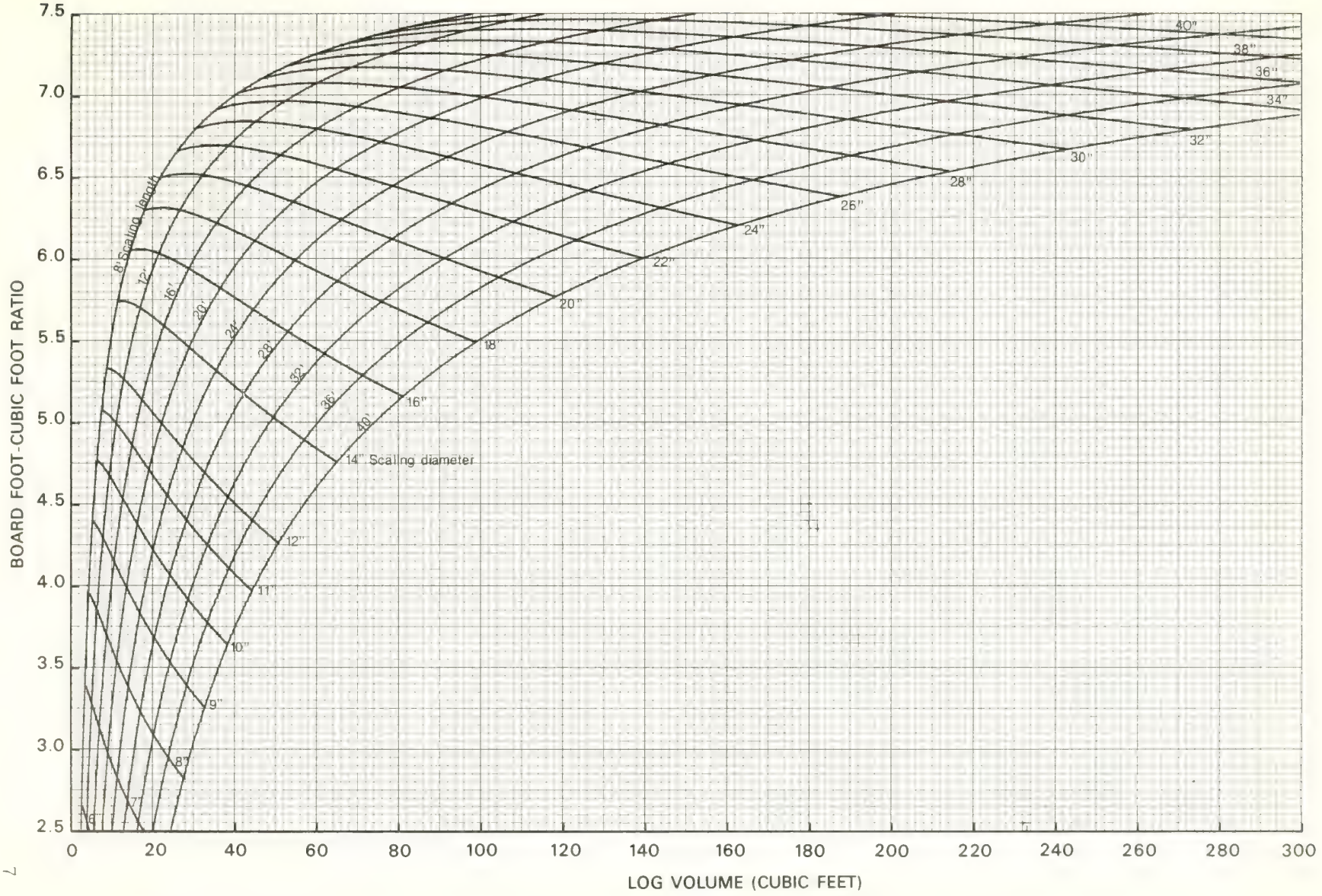


Figure 4.—Board-foot to cubic-foot ratio versus cubic volume. (Scribner log equation for west side scaling practice; taper of 1 inch in 8 feet; cubic volumes include 8 inches trim allowance.)

The plot is based on the scribner formula rule,[2/]

$$V_B = (0.79\ d_1'^2 - 2d_1' - 4)\ \frac{L'}{16},$$

which approximates the Scribner log rule to provide a continuous curve. Similar relationships can be obtained for other log rules and scaling practices. Cubic volumes were calculated by the Rapraeger rule,[3/]

$$V_C = \frac{\pi}{576}\ (d_1 + \frac{L}{16})^2\ L,$$

which assumes a taper of 1 inch in 8 feet. In calculating these cubic volumes, a trim allowance of 8 inches has been added to the scaling lengths,

$$L = L' + 8/12,$$

and one-half inch has been added to the scaling diameters,

$$d_1 = d_1' + 1/2.$$

This is to correspond with the west-side scaling practice of dropping all fractions of an inch from the scaling diameters and adding a trim allowance to the scaling lengths.

APPENDIX II

TABLES, GRAPHS, AND WORKSHEETS

The following tables, graphs, and worksheets are provided for determining the density index and for estimating log weights. Tables 1 and 2 are cubic volume tables for determining the density index. For convenience, a worksheet (fig. 26) is provided for computing a density index from a truckload of logs. Figure 27 is a worksheet for a moving average of the density index. Log weight estimates can be made from the graphs (figs. 5-25) or tables (tables 3-44) after the density index has been determined.

[2/] *Donald Bruce and Francis Schumacher. Forest mensuration. New York, McGraw-Hill Book Co., Inc., 483 p., 1960.*

[3/] *J. R. Dilworth. Log scaling and timber cruising. Corvallis, Oregon State University Book Stores, Inc., 448 p., 1965.*

Table 1.--Cubic log volumes for scaling lengths of 4 to 32 feet

LARGE END DIAMETER (INCHES)	LOG VOLUME (CUBIC FEET) ASSUMED TAPER OF 1 INCH PER 4 FEET, TRIM ALLOWANCE OF 1 INCH PER 4 FEET SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	17	18	20	22	24	26	28	30	32
6	.7	1.1	1.3	1.5	1.8	2.0	2.2	2.3	2.4	2.5	2.6	2.7	2.7	2.8	2.8	2.8
7	1.0	1.5	1.8	2.1	2.4	2.6	3.0	3.2	3.4	3.6	3.8	4.0	4.1	4.2	4.3	4.4
8	1.3	1.9	2.3	2.6	3.0	3.3	3.7	3.9	4.2	4.7	5.2	5.7	5.8	5.9	6.1	6.2
9	1.7	2.4	2.9	3.4	4.0	4.5	5.1	5.4	5.7	6.2	6.8	7.1	7.5	7.8	8.1	8.3
10	2.1	3.1	3.8	4.3	5.0	5.7	6.5	7.0	7.2	7.9	8.5	9.1	9.6	10.1	10.5	10.8
11	2.6	3.8	4.6	5.3	6.1	7.0	8.0	8.5	9.0	9.7	10.5	11.3	12.0	12.5	13.0	13.3
12	3.1	4.5	5.5	6.4	7.4	8.4	9.6	10.2	10.7	11.7	12.6	13.5	14.4	15.0	15.6	16.0
13	3.6	5.3	6.5	7.6	8.8	10.1	11.4	12.0	12.8	13.8	14.9	16.0	17.0	17.8	18.5	19.0
14	4.2	6.2	7.6	8.8	10.2	11.7	13.4	14.2	15.0	16.2	17.5	18.8	20.0	20.9	21.7	22.3
15	4.8	7.1	8.8	10.2	11.8	13.5	15.5	16.4	17.4	18.8	20.2	21.8	23.2	24.2	25.2	25.8
16	5.5	8.1	10.0	11.6	13.4	15.4	17.6	18.7	19.8	21.4	23.0	24.8	26.4	27.6	28.7	29.4
17	6.2	9.1	11.2	13.0	15.1	17.4	19.8	21.0	22.3	24.1	25.9	27.9	29.7	31.1	32.3	33.1
18	7.0	10.2	12.6	14.6	16.9	19.4	22.1	23.4	24.8	26.9	28.9	31.1	33.1	34.6	36.0	36.9
19	7.8	11.4	14.0	16.3	18.8	21.6	24.6	26.0	27.6	29.8	32.1	34.6	36.8	38.5	40.0	41.0
20	8.7	12.6	15.6	18.1	20.9	24.0	27.3	28.9	30.6	33.1	35.7	38.4	40.9	42.8	44.4	45.6
21	9.6	14.0	17.3	20.1	23.2	26.6	30.3	32.0	33.9	36.7	39.5	42.5	45.2	47.3	49.0	50.3
22	10.6	15.4	19.0	22.1	25.5	29.3	33.3	35.2	37.3	40.3	43.5	46.8	49.8	52.0	53.9	55.3
23	11.7	17.0	21.0	24.3	28.1	32.2	36.7	38.8	41.0	44.4	47.9	51.5	54.8	57.3	59.3	60.8
24	12.8	18.6	23.0	26.6	30.8	35.3	40.2	42.5	45.0	48.6	52.5	56.4	60.0	62.8	64.9	66.6
25	14.0	20.3	25.1	29.1	33.6	38.5	43.9	46.4	49.1	53.1	57.3	61.6	65.5	68.5	70.9	72.7
26	15.3	22.1	27.3	31.7	36.6	41.9	47.8	50.6	53.5	57.8	62.4	67.1	71.4	74.7	77.2	79.2
27	16.6	24.0	29.7	34.4	39.8	45.6	52.0	55.0	58.2	62.9	67.9	73.0	77.7	81.3	84.0	86.2
28	18.1	26.1	32.3	37.4	43.2	49.5	56.5	59.8	63.2	68.3	73.8	79.3	84.4	88.3	91.3	93.7
29	19.6	28.3	35.0	40.5	46.8	53.6	61.2	64.7	68.4	74.0	79.9	85.9	91.4	95.6	98.8	101.4
30	21.2	30.6	37.8	43.8	50.6	58.0	66.1	70.0	74.0	80.0	86.4	92.8	98.8	103.3	106.8	109.6
31	22.9	33.0	40.8	47.2	54.6	62.5	71.3	75.4	79.8	86.2	93.1	100.1	106.5	111.4	115.2	118.2
32	24.6	35.4	43.8	50.7	58.6	67.1	76.5	81.0	85.6	92.6	100.1	107.6	114.5	119.8	123.8	127.1
33	26.4	38.0	47.0	54.4	62.9	72.0	82.1	86.9	91.8	99.3	107.3	115.4	122.8	128.4	132.8	136.3
34	28.3	40.8	50.4	58.3	67.4	77.2	88.0	93.1	98.4	106.4	115.0	123.6	131.6	137.6	142.3	146.1
35	30.3	43.6	53.9	62.4	72.1	82.6	94.1	99.6	105.2	113.8	123.0	132.2	140.7	147.1	152.2	156.2
36	32.3	46.5	57.5	66.5	76.9	88.1	100.4	106.2	112.2	121.4	131.2	141.0	150.1	156.9	162.3	166.5
37	34.4	49.5	61.2	70.8	81.9	93.8	106.9	113.1	119.5	129.3	139.7	150.2	159.9	167.2	172.9	177.4
38	36.6	52.7	65.1	75.3	87.1	99.8	113.7	120.3	127.1	137.5	148.6	159.7	170.0	177.8	183.9	188.7
39	38.9	56.0	69.2	80.0	92.5	106.0	120.8	127.8	135.0	146.0	157.8	169.6	180.5	188.7	195.2	200.3
40	41.2	59.4	73.4	84.9	98.2	112.5	128.2	135.6	143.3	155.0	167.4	179.9	191.5	200.2	207.1	212.5
41	43.6	62.9	77.8	90.0	104.1	119.3	135.9	143.8	151.9	164.3	177.5	190.7	203.0	212.2	219.5	225.2
42	46.1	66.5	82.3	95.2	110.1	126.1	143.8	152.1	160.7	173.8	187.7	201.7	214.7	224.4	232.1	238.1
43	48.7	70.2	86.9	100.5	116.3	133.2	151.8	160.6	169.7	183.5	198.2	213.0	226.7	237.0	245.1	251.4
44	51.3	74.0	91.6	106.0	122.6	140.4	160.0	169.3	178.9	193.5	208.9	224.5	239.0	249.9	258.4	265.1
45	54.0	77.9	96.4	111.6	129.0	147.8	168.4	178.2	188.3	203.6	219.9	236.3	251.5	263.0	272.0	279.0
46	56.8	81.9	101.4	117.3	135.7	155.4	177.1	187.4	198.0	214.1	231.2	248.4	264.4	276.4	285.9	293.3
47	59.7	86.0	106.5	123.2	142.5	163.2	186.0	196.8	208.0	224.9	242.8	260.9	277.8	290.4	300.4	308.1
48	62.6	90.2	111.7	129.3	149.5	171.2	195.0	206.4	218.1	235.9	254.7	273.6	291.3	304.5	315.0	323.1
49	65.6	94.5	117.0	135.4	156.6	179.3	204.2	216.2	228.4	247.0	266.8	286.6	305.1	319.0	329.9	338.4
50	68.7	98.9	122.5	141.8	163.9	187.7	213.8	226.3	239.1	258.6	279.2	300.1	319.5	334.0	345.4	354.2
51	71.8	103.4	128.1	148.2	171.4	196.2	223.5	236.6	250.0	270.4	292.0	313.8	334.1	349.3	361.2	370.4
52	75.0	108.0	133.8	154.8	179.0	204.9	233.4	247.1	261.1	282.4	304.9	327.6	348.8	364.8	377.2	386.9
53	78.3	112.8	139.7	161.6	186.9	213.9	243.6	258.0	272.6	294.8	318.3	342.0	364.1	380.7	393.7	403.8
54	81.6	117.6	145.7	168.5	194.9	223.1	254.1	269.1	284.4	307.5	332.0	356.7	379.8	397.1	410.7	421.2
55	85.0	122.5	151.8	175.6	203.1	232.5	264.9	280.5	296.4	320.5	346.1	371.8	395.9	414.0	428.1	439.1
56	88.5	127.5	158.0	182.8	211.4	242.0	275.8	292.1	308.6	333.7	360.3	387.2	412.4	431.3	446.1	457.5
57	92.0	132.7	164.4	190.2	220.0	251.9	287.0	304.0	321.2	347.3	375.1	403.0	429.4	449.1	464.6	476.5
58	95.7	138.0	171.0	197.9	228.9	262.0	298.6	316.3	334.2	361.4	390.3	419.3	446.8	467.4	483.5	496.0
59	99.4	143.4	177.7	205.6	237.9	272.3	310.3	328.8	347.4	375.7	405.7	435.9	464.5	486.0	502.7	515.8
60	103.2	148.9	184.6	213.6	247.1	282.8	322.3	341.5	360.9	390.3	421.4	452.8	482.6	505.0	522.3	535.9

Table 2.--Cubic log volumes for scaling lengths of 34 to 60 feet

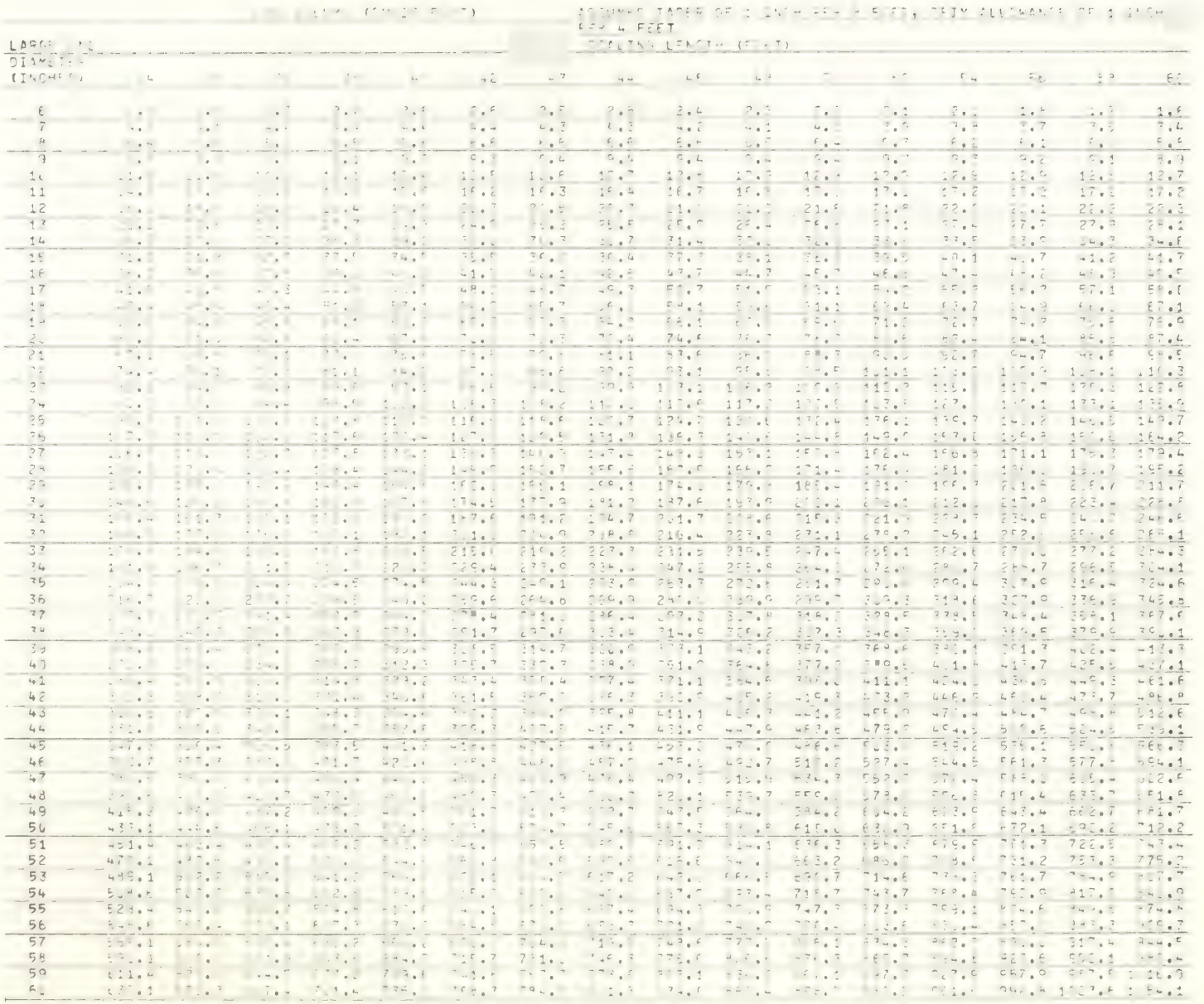


Table 3.--Log weights for scaling lengths of 4 to 32 feet: density index = 30 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

Table 4.--Log weights for scaling lengths of 34 to 60 feet: density index = 30 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (TONS*) FOR DENSITY INDEX

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
6	.15	.15	.15	.15	.14	.14	.14	.14	.14	.14	.13	.13	.13	.13	.13	.12
7	.13	.13	.13	.13	.13	.13	.13	.13	.12	.12	.12	.12	.12	.11	.11	.11
8	.12	.12	.12	.12	.12	.12	.12	.11	.11	.11	.11	.11	.11	.11	.10	.10
9	.27	.27	.27	.27	.26	.26	.26	.26	.25	.25	.25	.25	.25	.24	.24	.24
10	.37	.37	.37	.36	.36	.36	.36	.35	.35	.35	.35	.34	.34	.34	.34	.33
11	.47	.47	.46	.46	.46	.45	.45	.45	.44	.44	.44	.43	.43	.43	.43	.42
12	.57	.57	.56	.56	.56	.55	.55	.55	.54	.54	.53	.53	.53	.52	.52	.52
13	.67	.67	.66	.66	.65	.65	.65	.64	.64	.63	.63	.63	.62	.62	.61	.61
14	.78	.77	.77	.76	.76	.75	.75	.74	.74	.73	.73	.72	.72	.71	.71	.70
15	.89	.88	.87	.87	.86	.86	.85	.85	.84	.83	.83	.82	.82	.81	.81	.80
16	1.00	.99	.98	.98	.97	.96	.96	.95	.94	.94	.93	.93	.92	.91	.91	.90
17	1.11	1.10	1.09	1.09	1.08	1.07	1.07	1.06	1.05	1.05	1.04	1.03	1.03	1.02	1.01	1.01
18	1.23	1.22	1.21	1.20	1.19	1.18	1.18	1.17	1.16	1.16	1.15	1.14	1.14	1.13	1.12	1.12
19	1.35	1.34	1.33	1.32	1.31	1.30	1.29	1.28	1.28	1.27	1.26	1.25	1.25	1.24	1.23	1.23
20	1.47	1.46	1.45	1.44	1.43	1.42	1.41	1.40	1.39	1.38	1.38	1.37	1.36	1.35	1.35	1.34
21	1.60	1.59	1.57	1.56	1.55	1.54	1.53	1.52	1.51	1.50	1.49	1.48	1.47	1.47	1.46	1.45
22	1.73	1.72	1.70	1.69	1.68	1.67	1.66	1.64	1.63	1.62	1.61	1.60	1.59	1.58	1.57	1.56
23	1.87	1.85	1.84	1.82	1.81	1.80	1.78	1.77	1.76	1.75	1.74	1.73	1.72	1.71	1.70	1.69
24	2.01	1.99	1.98	1.96	1.95	1.93	1.92	1.91	1.89	1.88	1.87	1.86	1.85	1.84	1.83	1.82
25	2.15	2.14	2.12	2.11	2.09	2.08	2.07	2.05	2.04	2.03	2.01	2.00	1.99	1.98	1.97	1.96
26	2.30	2.29	2.27	2.26	2.24	2.23	2.21	2.20	2.19	2.17	2.16	2.15	2.14	2.13	2.12	2.11
27	2.46	2.44	2.43	2.41	2.40	2.38	2.37	2.35	2.34	2.33	2.31	2.30	2.29	2.28	2.27	2.26
28	2.62	2.60	2.59	2.57	2.56	2.54	2.53	2.51	2.50	2.48	2.47	2.46	2.45	2.44	2.43	2.41
29	2.78	2.77	2.75	2.74	2.72	2.71	2.69	2.68	2.66	2.65	2.64	2.62	2.61	2.60	2.59	2.58
30	2.95	2.94	2.92	2.91	2.89	2.88	2.86	2.85	2.83	2.82	2.81	2.79	2.78	2.77	2.76	2.75
31	3.13	3.11	3.10	3.08	3.07	3.05	3.04	3.02	3.01	3.00	2.98	2.97	2.96	2.95	2.93	2.92
32	3.31	3.29	3.28	3.26	3.25	3.23	3.22	3.20	3.19	3.17	3.16	3.15	3.13	3.12	3.11	3.10
33	3.49	3.48	3.46	3.45	3.43	3.42	3.40	3.39	3.37	3.36	3.35	3.33	3.32	3.31	3.29	3.28
34	3.68	3.67	3.65	3.64	3.62	3.61	3.59	3.58	3.56	3.55	3.53	3.52	3.51	3.49	3.48	3.47
35	3.88	3.86	3.85	3.83	3.82	3.80	3.79	3.77	3.76	3.74	3.73	3.72	3.70	3.69	3.68	3.66
36	4.08	4.06	4.05	4.03	4.02	4.00	3.99	3.97	3.96	3.94	3.93	3.91	3.90	3.89	3.87	3.86
37	4.28	4.27	4.25	4.24	4.22	4.21	4.19	4.18	4.16	4.15	4.13	4.12	4.11	4.09	4.08	4.06
38	4.49	4.48	4.46	4.45	4.43	4.42	4.40	4.39	4.37	4.36	4.34	4.33	4.31	4.30	4.29	4.27
39	4.71	4.69	4.68	4.66	4.65	4.63	4.62	4.60	4.59	4.57	4.56	4.54	4.53	4.52	4.50	4.49
40	4.93	4.91	4.90	4.88	4.87	4.85	4.84	4.82	4.81	4.79	4.78	4.76	4.75	4.73	4.72	4.71
41	5.15	5.14	5.12	5.11	5.09	5.08	5.06	5.05	5.03	5.02	5.00	4.99	4.97	4.96	4.95	4.93
42	5.38	5.36	5.35	5.33	5.32	5.30	5.29	5.27	5.26	5.24	5.23	5.21	5.20	5.18	5.17	5.16
43	5.61	5.60	5.58	5.57	5.55	5.54	5.52	5.51	5.49	5.48	5.46	5.45	5.43	5.42	5.40	5.39
44	5.85	5.84	5.82	5.81	5.79	5.78	5.76	5.75	5.73	5.72	5.70	5.69	5.67	5.66	5.64	5.63
45	6.10	6.08	6.07	6.05	6.04	6.02	6.01	5.99	5.98	5.96	5.95	5.93	5.92	5.90	5.89	5.87
46	6.35	6.33	6.32	6.30	6.29	6.27	6.26	6.24	6.23	6.21	6.20	6.18	6.17	6.15	6.14	6.12
47	6.60	6.58	6.57	6.55	6.54	6.52	6.51	6.49	6.48	6.46	6.45	6.43	6.42	6.40	6.39	6.37
48	6.85	6.84	6.82	6.81	6.79	6.78	6.76	6.75	6.73	6.72	6.70	6.69	6.67	6.66	6.64	6.63
49	7.12	7.10	7.09	7.07	7.06	7.04	7.03	7.01	7.00	6.98	6.97	6.95	6.94	6.92	6.91	6.89
50	7.38	7.37	7.35	7.34	7.32	7.31	7.29	7.28	7.26	7.25	7.23	7.22	7.20	7.19	7.17	7.16
51	7.65	7.64	7.62	7.61	7.59	7.58	7.56	7.55	7.53	7.52	7.50	7.49	7.47	7.46	7.44	7.43
52	7.93	7.91	7.90	7.88	7.87	7.85	7.84	7.82	7.81	7.79	7.78	7.76	7.75	7.73	7.72	7.70
53	8.21	8.19	8.18	8.16	8.15	8.13	8.12	8.10	8.09	8.07	8.06	8.04	8.03	8.01	8.00	7.98
54	8.49	8.47	8.46	8.44	8.43	8.41	8.40	8.38	8.37	8.35	8.34	8.32	8.31	8.29	8.28	8.26
55	8.77	8.75	8.74	8.72	8.71	8.69	8.68	8.66	8.65	8.63	8.62	8.60	8.59	8.57	8.56	8.54
56	9.05	9.04	9.02	9.01	8.99	8.98	8.96	8.95	8.93	8.92	8.90	8.89	8.87	8.86	8.84	8.83
57	9.34	9.32	9.31	9.29	9.28	9.26	9.25	9.23	9.22	9.20	9.19	9.17	9.16	9.14	9.13	9.11
58	9.63	9.61	9.60	9.58	9.57	9.55	9.54	9.52	9.51	9.49	9.48	9.46	9.45	9.43	9.42	9.40
59	9.92	9.90	9.89	9.87	9.86	9.84	9.83	9.81	9.80	9.78	9.77	9.75	9.74	9.72	9.71	9.69
60	10.21	10.19	10.18	10.16	10.15	10.13	10.12	10.10	10.09	10.07	10.06	10.04	10.03	10.01	10.00	9.98

Table 5.--Log weights for scaling lengths of 4 to 32 feet: density index = 32 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (WTBS*) FOR DENSITY INDEX=32

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
6	.06	.08	.10	.05	.06	.07	.07	.07	.08	.08	.09	.09	.09	.09	.09
7	.07	.09	.06	.07	.08	.09	.10	.11	.11	.12	.12	.13	.13	.14	.14	.14
8	.09	.08	.09	.10	.11	.12	.14	.14	.15	.16	.17	.16	.19	.19	.20	.21
9	.05	.11	.11	.12	.14	.16	.18	.19	.20	.21	.23	.24	.25	.26	.27	.28
10	.07	.11	.13	.16	.18	.21	.23	.24	.25	.27	.29	.31	.32	.34	.35	.36
11	.11	.14	.16	.19	.22	.25	.28	.30	.31	.34	.36	.38	.40	.42	.44	.46
12	.11	.14	.19	.23	.27	.31	.34	.36	.38	.41	.44	.47	.50	.52	.54	.57
13	.12	.17	.22	.27	.32	.37	.41	.43	.45	.49	.53	.56	.60	.63	.66	.69
14	.13	.17	.22	.32	.37	.43	.48	.51	.53	.58	.63	.66	.71	.74	.78	.82
15	.15	.19	.25	.37	.43	.50	.56	.60	.62	.67	.73	.77	.82	.87	.92	.96
16	.16	.21	.28	.42	.50	.57	.64	.67	.71	.77	.84	.91	.95	1.01	1.06	1.11
17	.18	.24	.31	.48	.56	.65	.73	.77	.81	.88	.96	1.02	1.09	1.15	1.22	1.28
18	.21	.28	.36	.54	.64	.73	.82	.87	.91	1.00	1.08	1.16	1.24	1.31	1.39	1.45
19	.23	.32	.40	.61	.71	.82	.92	.97	1.02	1.12	1.21	1.30	1.39	1.48	1.56	1.64
20	.26	.36	.45	.67	.79	.91	1.03	1.08	1.14	1.26	1.36	1.46	1.56	1.66	1.75	1.84
21	.29	.40	.50	.74	.88	1.01	1.14	1.20	1.26	1.39	1.51	1.62	1.73	1.84	1.95	2.05
22	.32	.44	.55	.81	.96	1.11	1.25	1.32	1.39	1.53	1.66	1.78	1.90	2.02	2.14	2.25
23	.35	.48	.60	.88	1.05	1.22	1.38	1.45	1.53	1.68	1.82	1.96	2.09	2.21	2.34	2.46
24	.38	.52	.65	.96	1.15	1.33	1.51	1.59	1.67	1.84	2.00	2.15	2.29	2.43	2.57	2.70
25	.41	.56	.71	1.04	1.25	1.45	1.64	1.73	1.82	2.01	2.18	2.35	2.50	2.65	2.80	2.95
26	.45	.61	.77	1.13	1.35	1.57	1.78	1.88	1.98	2.18	2.37	2.55	2.74	2.92	3.11	3.27
27	.49	.66	.83	1.22	1.46	1.70	1.92	2.03	2.14	2.36	2.57	2.77	2.97	3.17	3.36	3.55
28	.53	.71	.90	1.32	1.58	1.83	2.07	2.19	2.31	2.54	2.77	2.99	3.21	3.42	3.64	3.84
29	.57	.77	.97	1.43	1.71	1.97	2.23	2.36	2.49	2.74	2.99	3.23	3.46	3.69	3.92	4.14
30	.62	.83	1.04	1.54	1.84	2.11	2.39	2.53	2.67	2.94	3.21	3.47	3.72	3.97	4.22	4.45
31	.67	.89	1.12	1.65	1.97	2.26	2.56	2.71	2.86	3.15	3.43	3.71	3.98	4.25	4.51	4.76
32	.72	.96	1.20	1.77	2.11	2.42	2.74	2.90	3.06	3.37	3.67	3.97	4.26	4.55	4.83	5.10
33	.78	1.04	1.30	1.92	2.29	2.63	2.98	3.15	3.32	3.66	3.99	4.31	4.63	4.94	5.24	5.53
34	.84	1.12	1.40	2.07	2.47	2.84	3.21	3.40	3.58	3.94	4.30	4.65	4.99	5.32	5.65	5.96
35	.90	1.20	1.50	2.21	2.65	3.04	3.44	3.64	3.84	4.23	4.61	4.99	5.36	5.71	6.06	6.40
36	.91	1.28	1.60	2.36	2.82	3.24	3.67	3.89	4.09	4.51	4.92	5.32	5.71	6.09	6.46	6.82
37	.96	1.43	1.79	2.64	3.16	3.63	4.11	4.35	4.58	5.05	5.51	5.96	6.40	6.82	7.24	7.64
38	1.02	1.51	2.01	2.97	3.55	4.08	4.62	4.89	5.15	5.68	6.20	6.70	7.20	7.67	8.14	8.59
39	1.07	1.59	2.11	3.11	3.72	4.27	4.84	5.12	5.39	5.94	6.48	7.01	7.53	8.03	8.52	8.99
40	1.13	1.68	2.22	3.28	3.92	4.50	5.09	5.39	5.68	6.26	6.83	7.39	7.93	8.46	8.97	9.47
41	1.19	1.76	2.34	3.45	4.12	4.73	5.35	5.66	5.96	6.57	7.17	7.76	8.33	8.88	9.42	9.94
42	1.25	1.85	2.45	3.62	4.32	4.96	5.61	5.93	6.25	6.89	7.52	8.13	8.73	9.31	9.87	10.42
43	1.31	1.94	2.57	3.79	4.52	5.19	5.87	6.21	6.54	7.21	7.87	8.51	9.14	9.74	10.33	10.90
44	1.37	2.03	2.69	3.96	4.73	5.43	6.14	6.49	6.84	7.54	8.23	8.90	9.56	10.19	10.80	11.40
45	1.43	2.12	2.81	4.14	4.94	5.67	6.41	6.78	7.14	7.87	8.59	9.29	9.98	10.64	11.28	11.90
46	1.49	2.21	2.93	4.31	5.15	5.91	6.68	7.06	7.44	8.20	8.95	9.68	10.40	11.09	11.76	12.41
47	1.55	2.30	3.05	4.49	5.36	6.15	6.96	7.35	7.75	8.54	9.32	10.08	10.83	11.55	12.25	12.93
48	1.61	2.39	3.17	4.67	5.57	6.40	7.23	7.65	8.05	8.88	9.68	10.48	11.25	12.00	12.73	13.43
49	1.68	2.49	3.30	4.85	5.79	6.64	7.51	7.94	8.36	9.21	10.05	10.87	11.68	12.46	13.21	13.94
50	1.74	2.58	3.42	5.03	6.00	6.89	7.78	8.23	8.66	9.55	10.41	11.27	12.10	12.91	13.69	14.45
51	1.84	2.74	3.63	5.34	6.37	7.31	8.26	8.73	9.19	10.13	11.05	11.95	12.84	13.69	14.52	15.32
52	1.91	2.85	3.78	5.56	6.63	7.61	8.60	9.09	9.57	10.55	11.50	12.44	13.36	14.25	15.11	15.95
53	1.98	2.96	3.93	5.78	6.90	7.92	8.94	9.45	9.95	10.97	11.96	12.93	13.89	14.81	15.71	16.58
54	2.06	3.07	4.08	6.00	7.16	8.22	9.28	9.81	10.33	11.38	12.41	13.42	14.41	15.37	16.30	17.21
55	2.14	3.19	4.23	6.22	7.42	8.52	9.62	10.17	10.71	11.80	12.86	13.91	14.94	15.93	16.90	17.84
56	2.21	3.30	4.38	6.44	7.69	8.82	9.97	10.53	11.09	12.22	13.32	14.40	15.47	16.50	17.50	18.47
57	2.29	3.41	4.53	6.66	7.95	9.13	10.31	10.90	11.47	12.64	13.78	14.90	15.99	17.06	18.09	19.10
58	2.36	3.52	4.68	6.88	8.21	9.43	10.65	11.26	11.85	13.06	14.24	15.39	16.52	17.62	18.69	19.73
59	2.44	3.63	4.83	7.10	8.47	9.73	10.99	11.62	12.23	13.48	14.69	15.89	17.05	18.18	19.29	20.36
60	2.51	3.74	4.98	7.32	8.74	10.03	11.33	11.98	12.61	13.89	15.15	16.38	17.59	18.75	19.89	20.99

* 1MBF=1

Table 6.--Log weights for scaling lengths of 34 to 60 feet: density index = 32 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (WIDE*) FOR DENSITY INDEX

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
6	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
7	.13	.13	.13	.13	.14	.14	.14	.14	.14	.13	.13	.13	.12	.12	.11	.11
8	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.20	.19
9	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
10	.37	.37	.37	.37	.40	.40	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41
11	.47	.47	.47	.51	.51	.52	.52	.53	.54	.54	.54	.55	.55	.55	.55	.55
12	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.65	.66	.66	.67	.68	.68	.69	.70	.70	.71	.71
13	.71	.71	.71	.71	.76	.76	.81	.81	.82	.83	.84	.85	.87	.88	.89	.89
14	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.81	.83	.86	.87	.88	.89	.90	.91	.93	.94	.96	.97
15	1.07	1.07	1.07	1.07	1.11	1.14	1.15	1.17	1.19	1.22	1.24	1.26	1.28	1.30	1.32	1.33
16	1.16	1.16	1.16	1.16	1.20	1.23	1.25	1.26	1.28	1.31	1.33	1.35	1.37	1.39	1.41	1.43
17	1.24	1.25	1.25	1.25	1.29	1.32	1.35	1.36	1.38	1.41	1.43	1.45	1.48	1.50	1.52	1.54
18	1.33	1.34	1.34	1.34	1.37	1.41	1.44	1.46	1.48	1.51	1.53	1.56	1.58	1.61	1.63	1.65
19	1.42	1.43	1.43	1.44	1.47	1.50	1.53	1.56	1.58	1.61	1.64	1.66	1.69	1.72	1.74	1.77
20	1.53	1.53	1.53	1.54	1.57	1.60	1.63	1.66	1.69	1.72	1.75	1.78	1.81	1.83	1.86	1.89
21	1.63	1.63	1.64	1.64	1.68	1.71	1.74	1.77	1.80	1.83	1.86	1.89	1.92	1.95	1.98	2.01
22	1.74	1.74	1.74	1.75	1.78	1.82	1.85	1.88	1.91	1.94	1.97	2.00	2.03	2.07	2.10	2.13
23	1.85	1.85	1.85	1.86	1.89	1.93	1.96	1.99	2.02	2.06	2.09	2.12	2.15	2.19	2.22	2.25
24	1.96	1.96	1.97	1.97	2.01	2.04	2.08	2.11	2.14	2.18	2.21	2.24	2.28	2.31	2.35	2.38
25	2.08	2.08	2.09	2.09	2.13	2.16	2.20	2.23	2.27	2.30	2.34	2.37	2.41	2.45	2.48	2.52
26	2.20	2.20	2.21	2.21	2.25	2.29	2.32	2.36	2.40	2.44	2.47	2.51	2.55	2.59	2.63	2.66
27	2.32	2.33	2.33	2.34	2.38	2.42	2.46	2.50	2.53	2.57	2.61	2.65	2.69	2.73	2.77	2.81
28	2.45	2.46	2.46	2.47	2.51	2.55	2.59	2.63	2.67	2.71	2.75	2.79	2.83	2.87	2.91	2.95
29	2.58	2.59	2.59	2.60	2.64	2.68	2.72	2.76	2.80	2.85	2.89	2.93	2.97	3.01	3.06	3.10
30	2.71	2.72	2.72	2.73	2.77	2.81	2.86	2.90	2.94	2.98	3.03	3.07	3.11	3.16	3.20	3.25
31	2.84	2.85	2.86	2.86	2.91	2.95	2.99	3.04	3.08	3.13	3.17	3.22	3.26	3.31	3.35	3.40
32	2.98	2.99	2.99	3.00	3.05	3.09	3.14	3.18	3.23	3.27	3.32	3.37	3.41	3.46	3.51	3.56
33	3.12	3.13	3.13	3.14	3.19	3.23	3.28	3.33	3.38	3.42	3.47	3.52	3.57	3.62	3.67	3.72
34	3.26	3.27	3.28	3.28	3.33	3.38	3.43	3.48	3.53	3.58	3.63	3.68	3.73	3.78	3.83	3.89
35	3.41	3.42	3.42	3.43	3.48	3.53	3.58	3.63	3.69	3.74	3.79	3.84	3.90	3.95	4.00	4.06
36	3.55	3.56	3.57	3.58	3.63	3.68	3.74	3.79	3.84	3.90	3.95	4.01	4.06	4.12	4.18	4.23
37	3.70	3.71	3.72	3.73	3.78	3.84	3.89	3.95	4.00	4.06	4.12	4.17	4.23	4.29	4.35	4.41
38	3.85	3.86	3.87	3.88	3.94	3.99	4.05	4.11	4.17	4.23	4.28	4.34	4.40	4.46	4.52	4.58
39	4.00	4.01	4.02	4.03	4.09	4.15	4.21	4.27	4.33	4.39	4.45	4.51	4.57	4.63	4.70	4.76
40	4.15	4.16	4.17	4.18	4.24	4.30	4.37	4.43	4.49	4.55	4.62	4.68	4.74	4.81	4.87	4.94
41	4.30	4.31	4.32	4.33	4.40	4.46	4.53	4.59	4.66	4.72	4.79	4.85	4.92	4.98	5.05	5.12
42	4.45	4.46	4.48	4.49	4.56	4.62	4.69	4.76	4.83	4.89	4.96	5.03	5.10	5.16	5.23	5.30
43	4.60	4.62	4.63	4.64	4.72	4.78	4.86	4.93	5.00	5.07	5.14	5.21	5.28	5.35	5.42	5.49
44	4.76	4.77	4.79	4.80	4.88	4.95	5.02	5.10	5.17	5.24	5.32	5.39	5.46	5.54	5.61	5.69
45	4.92	4.93	4.95	4.96	5.04	5.11	5.19	5.27	5.34	5.42	5.50	5.57	5.65	5.73	5.80	5.88
46	5.08	5.09	5.11	5.12	5.20	5.28	5.36	5.44	5.52	5.60	5.68	5.76	5.84	5.92	6.00	6.08
47	5.24	5.26	5.27	5.29	5.37	5.45	5.54	5.62	5.70	5.78	5.87	5.95	6.03	6.12	6.20	6.28
48	5.41	5.42	5.44	5.46	5.54	5.63	5.71	5.80	5.88	5.97	6.05	6.14	6.23	6.31	6.40	6.49
49	5.57	5.59	5.61	5.63	5.72	5.80	5.89	5.98	6.07	6.16	6.25	6.34	6.43	6.52	6.61	6.70
50	5.74	5.76	5.78	5.80	5.89	5.98	6.07	6.16	6.26	6.35	6.44	6.54	6.63	6.72	6.82	6.91
51	5.91	5.93	5.95	5.97	6.07	6.16	6.26	6.35	6.45	6.54	6.64	6.74	6.83	6.93	7.03	7.13
52	6.08	6.10	6.12	6.15	6.24	6.34	6.44	6.54	6.64	6.74	6.84	6.94	7.04	7.14	7.24	7.34
53	6.25	6.27	6.30	6.32	6.42	6.52	6.62	6.73	6.83	6.93	7.04	7.14	7.25	7.35	7.46	7.56
54	6.42	6.45	6.47	6.50	6.60	6.71	6.81	6.92	7.03	7.13	7.24	7.35	7.46	7.57	7.68	7.79
55	6.60	6.63	6.65	6.68	6.79	6.89	7.00	7.11	7.22	7.33	7.45	7.56	7.67	7.78	7.90	8.01
56	6.78	6.81	6.83	6.86	6.97	7.08	7.19	7.31	7.42	7.53	7.65	7.77	7.88	8.00	8.12	8.23
57	6.96	6.99	7.02	7.05	7.16	7.27	7.39	7.50	7.62	7.74	7.86	7.98	8.10	8.22	8.34	8.46
58	7.14	7.17	7.20	7.23	7.35	7.46	7.58	7.70	7.82	7.94	8.07	8.19	8.31	8.44	8.56	8.69
59	7.32	7.35	7.38	7.41	7.53	7.65	7.78	7.90	8.02	8.15	8.27	8.40	8.53	8.66	8.79	8.92
60	7.50	7.53	7.56	7.60	7.72	7.85	7.97	8.10	8.23	8.36	8.49	8.62	8.75	8.88	9.01	9.15

* [illegible] SCRIBNER

Table 7.--Log weights for scaling lengths of 4 to 32 feet: density index = 34 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KIPS*) FOR DENSITY INDEX=34

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	17	18	20	22	24	26	28	30	32
6	.06	.08	.09	.11	.13	.15	.17	.18	.19	.21	.23	.25	.27	.29	.31	.33
7	.08	.11	.13	.15	.17	.19	.21	.23	.25	.28	.30	.32	.34	.36	.38	.41
8	.10	.14	.17	.19	.22	.25	.28	.29	.31	.35	.38	.41	.44	.47	.50	.53
9	.13	.17	.21	.24	.27	.31	.34	.36	.38	.43	.47	.51	.54	.58	.62	.66
10	.16	.21	.25	.29	.33	.37	.41	.43	.46	.52	.57	.61	.66	.70	.75	.80
11	.19	.25	.30	.34	.39	.44	.49	.51	.54	.61	.67	.73	.78	.84	.89	.95
12	.23	.29	.35	.40	.46	.52	.57	.60	.64	.72	.79	.85	.92	.98	1.05	1.12
13	.27	.34	.41	.47	.53	.60	.67	.70	.74	.83	.91	.99	1.06	1.14	1.22	1.30
14	.31	.39	.47	.54	.62	.70	.77	.81	.86	.96	1.06	1.15	1.24	1.33	1.42	1.51
15	.35	.44	.53	.62	.71	.80	.89	.93	.98	1.10	1.21	1.32	1.42	1.52	1.63	1.74
16	.40	.50	.60	.70	.80	.91	1.01	1.06	1.12	1.25	1.37	1.49	1.61	1.73	1.85	1.97
17	.45	.56	.67	.78	.90	1.02	1.13	1.19	1.25	1.40	1.54	1.67	1.81	1.94	2.08	2.21
18	.50	.62	.75	.87	1.00	1.13	1.26	1.32	1.39	1.55	1.71	1.86	2.01	2.16	2.31	2.46
19	.55	.69	.83	.96	1.10	1.25	1.39	1.46	1.53	1.71	1.88	2.05	2.22	2.38	2.55	2.71
20	.61	.76	.91	1.06	1.21	1.37	1.53	1.60	1.68	1.88	2.06	2.25	2.43	2.61	2.79	2.97
21	.67	.83	1.00	1.16	1.33	1.50	1.67	1.76	1.84	2.05	2.26	2.46	2.66	2.86	3.06	3.25
22	.73	.91	1.09	1.27	1.45	1.64	1.82	1.91	2.01	2.24	2.46	2.68	2.90	3.12	3.33	3.55
23	.80	.99	1.19	1.38	1.58	1.78	1.98	2.08	2.18	2.43	2.67	2.91	3.15	3.38	3.62	3.85
24	.86	1.08	1.29	1.50	1.72	1.93	2.15	2.25	2.36	2.63	2.89	3.15	3.40	3.66	3.91	4.16
25	.93	1.16	1.39	1.62	1.85	2.08	2.31	2.43	2.54	2.83	3.11	3.39	3.67	3.94	4.22	4.49
26	1.00	1.24	1.49	1.73	1.98	2.23	2.48	2.60	2.73	3.04	3.34	3.64	3.93	4.23	4.52	4.82
27	1.07	1.33	1.59	1.85	2.11	2.38	2.64	2.77	2.91	3.24	3.56	3.88	4.19	4.51	4.82	5.13
28	1.14	1.42	1.69	1.97	2.25	2.53	2.81	2.95	3.09	3.44	3.78	4.12	4.45	4.79	5.12	5.45
29	1.21	1.51	1.80	2.09	2.38	2.68	2.98	3.12	3.28	3.64	4.00	4.36	4.71	5.07	5.42	5.77
30	1.28	1.59	1.90	2.21	2.52	2.83	3.14	3.30	3.46	3.85	4.23	4.60	4.98	5.35	5.72	6.09
31	1.35	1.68	2.00	2.33	2.65	2.98	3.31	3.47	3.64	4.05	4.45	4.85	5.24	5.63	6.03	6.42
32	1.42	1.77	2.11	2.45	2.79	3.13	3.48	3.65	3.83	4.26	4.68	5.10	5.51	5.92	6.33	6.74
33	1.50	1.86	2.22	2.57	2.93	3.29	3.65	3.84	4.02	4.47	4.91	5.35	5.78	6.21	6.64	7.07
34	1.57	1.95	2.33	2.70	3.07	3.45	3.83	4.02	4.21	4.68	5.14	5.60	6.05	6.50	6.95	7.40
35	1.65	2.05	2.44	2.83	3.22	3.61	4.00	4.20	4.40	4.89	5.37	5.85	6.32	6.79	7.26	7.73
36	1.73	2.14	2.55	2.95	3.36	3.77	4.18	4.39	4.59	5.10	5.61	6.10	6.59	7.08	7.57	8.06
37	1.81	2.24	2.66	3.08	3.50	3.93	4.36	4.57	4.79	5.32	5.84	6.36	6.87	7.38	7.89	8.40
38	1.89	2.34	2.78	3.21	3.65	4.09	4.53	4.76	4.98	5.53	6.08	6.62	7.15	7.68	8.21	8.74
39	1.98	2.45	2.90	3.35	3.81	4.27	4.73	4.96	5.19	5.76	6.32	6.88	7.43	7.98	8.53	9.08
40	2.06	2.55	3.02	3.49	3.96	4.44	4.92	5.16	5.40	5.99	6.58	7.15	7.72	8.29	8.86	9.43
41	2.15	2.66	3.14	3.63	4.12	4.62	5.12	5.37	5.62	6.23	6.84	7.44	8.03	8.62	9.21	9.80
42	2.24	2.77	3.27	3.78	4.29	4.81	5.32	5.58	5.84	6.48	7.11	7.73	8.35	8.96	9.57	10.18
43	2.33	2.88	3.40	3.93	4.46	4.99	5.53	5.80	6.07	6.73	7.39	8.03	8.67	9.31	9.94	10.58
44	2.42	2.99	3.53	4.08	4.63	5.18	5.74	6.02	6.30	6.99	7.67	8.34	9.00	9.66	10.32	10.98
45	2.51	3.11	3.67	4.23	4.80	5.38	5.96	6.25	6.54	7.25	7.96	8.65	9.34	10.03	10.71	11.39
46	2.61	3.23	3.81	4.39	4.98	5.58	6.18	6.48	6.78	7.52	8.25	8.97	9.68	10.39	11.09	11.80
47	2.70	3.35	3.95	4.55	5.16	5.78	6.40	6.71	7.02	7.79	8.55	9.29	10.03	10.76	11.49	12.22
48	2.80	3.47	4.09	4.71	5.34	5.98	6.62	6.94	7.26	8.05	8.84	9.61	10.37	11.13	11.88	12.63
49	2.90	3.59	4.23	4.87	5.52	6.18	6.84	7.17	7.50	8.32	9.13	9.93	10.72	11.50	12.28	13.05
50	3.00	3.72	4.37	5.04	5.71	6.39	7.07	7.41	7.75	8.60	9.43	10.26	11.07	11.88	12.68	13.48
51	3.10	3.84	4.52	5.20	5.90	6.60	7.30	7.65	8.00	8.87	9.74	10.59	11.43	12.26	13.09	13.91
52	3.20	3.97	4.67	5.37	6.09	6.81	7.54	7.90	8.26	9.16	10.05	10.93	11.80	12.65	13.50	14.35
53	3.31	4.09	4.82	5.54	6.28	7.03	7.78	8.15	8.52	9.45	10.37	11.28	12.17	13.05	13.92	14.79
54	3.41	4.22	4.97	5.72	6.48	7.24	8.02	8.40	8.78	9.74	10.69	11.62	12.54	13.45	14.35	15.24
55	3.52	4.35	5.12	5.89	6.67	7.46	8.26	8.65	9.04	10.03	11.01	11.97	12.92	13.85	14.78	15.70
56	3.63	4.48	5.27	6.06	6.87	7.68	8.50	8.90	9.31	10.32	11.33	12.32	13.30	14.26	15.22	16.17
57	3.74	4.62	5.42	6.24	7.06	7.90	8.74	9.16	9.57	10.62	11.65	12.68	13.68	14.67	15.66	16.64
58	3.85	4.75	5.58	6.41	7.26	8.12	8.99	9.41	9.84	10.92	11.98	13.03	14.07	15.09	16.10	17.11
59	3.96	4.89	5.74	6.60	7.47	8.35	9.24	9.68	10.12	11.22	12.32	13.39	14.46	15.51	16.56	17.59
60	4.07	5.03	5.90	6.79	7.68	8.59	9.50	9.95	10.40	11.54	12.65	13.76	14.85	15.94	17.01	18.08

* 1 kip = 1,000 pounds

Table 8.--Log weights for scaling lengths of 34 to 60 feet: density index = 34 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LARGE END DIAMETER (INCHES)	LOG LENGTH (FEET)																									
	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
7	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11
8	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21
9	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31
10	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42	.42
11	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52
12	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
13	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73
14	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83
15	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94
16	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
17	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
18	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
19	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36
20	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46
21	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
22	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67
23	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78
24	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88
25	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99
26	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
27	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
28	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
29	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41
30	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
31	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62
32	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
33	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83
34	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93
35	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04
36	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
37	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
38	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
39	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46
40	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
41	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67
42	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77
43	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88
44	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98
45	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09
46	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19
47	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30
48	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40
49	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51
50	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61
51	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72
52	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82
53	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93
54	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03
55	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14
56	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24
57	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35
58	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45
59	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56	5.56
60	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66

Table 9.--Log weights for scaling lengths of 4 to 32 feet: density index = 36 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (POUNDS) FOR DENSITY INDEX 36

LARGE END DIAM TEE (INCHES)	SCALING LENGTH (FEET)															
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
6	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
7	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
8	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
9	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
10	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
11	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
12	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
13	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
14	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
15	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
16	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
17	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
18	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
19	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
20	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
21	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
22	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
23	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
24	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
25	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
26	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
27	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
28	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
29	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
30	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
31	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
32	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
33	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
34	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
35	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
36	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
37	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
38	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
39	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
40	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
41	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
42	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
43	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
44	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
45	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
46	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
47	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
48	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
49	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
50	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
51	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
52	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
53	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
54	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
55	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
56	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
57	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
58	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
59	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
60	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]

* [illegible]

Table 10.--Log weights for scaling lengths of 34 to 60 feet: density index = 36 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KIPS*) FOR DENSITY INDEX=36

LARGE-END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
				38			42	44	46	48	50	52	54	56	58	60
6	.1	.1	.1	.1	.1	.10	.10	.10	.09	.09	.08	.07	.07	.07	.06	.06
7	.1	.1	.1	.1	.1	.16	.15	.15	.15	.15	.15	.14	.14	.13	.13	.12
8	.2	.2	.2	.2	.2	.24	.24	.24	.24	.23	.23	.23	.22	.22	.21	.21
9	.3	.3	.3	.3	.3	.34	.34	.34	.34	.34	.34	.34	.33	.33	.33	.32
10	.4	.4	.4	.4	.4	.46	.46	.46	.46	.46	.46	.47	.47	.46	.46	.46
11	.5	.5	.5	.5	.5	.59	.59	.60	.60	.61	.61	.62	.62	.62	.62	.62
12	.6	.6	.7	.7	.7	.73	.74	.74	.75	.76	.77	.78	.79	.79	.80	.80
13	.8	.8	.8	.9	.9	.90	.91	.92	.93	.94	.95	.96	.97	.98	1.00	1.01
14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2
15	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.5
16	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.7	1.7
17	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.9	1.9	1.9	2.0	2.0	2.0
18	2.0	2.0	2.0	2.0	2.0	2.1	2.1	2.1	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.4
19	2.3	2.3	2.3	2.3	2.3	2.4	2.4	2.5	2.5	2.5	2.6	2.6	2.6	2.7	2.7	2.7
20	2.7	2.7	2.7	2.8	2.8	2.8	2.9	2.9	2.9	3.0	3.0	3.0	3.1	3.1	3.1	3.1
21	3.2	3.2	3.2	3.3	3.3	3.3	3.4	3.4	3.5	3.5	3.5	3.6	3.6	3.6	3.7	3.7
22	3.8	3.8	3.8	3.9	3.9	3.9	4.0	4.0	4.0	4.1	4.1	4.2	4.2	4.2	4.3	4.3
23	4.4	4.4	4.4	4.5	4.5	4.5	4.6	4.6	4.7	4.7	4.8	4.8	4.8	4.9	4.9	5.0
24	5.0	5.0	5.1	5.1	5.2	5.2	5.3	5.3	5.4	5.4	5.5	5.5	5.6	5.6	5.7	5.7
25	5.7	5.7	5.8	5.8	5.9	5.9	6.0	6.0	6.1	6.1	6.2	6.2	6.3	6.3	6.4	6.4
26	6.4	6.5	6.5	6.6	6.6	6.7	6.7	6.8	6.8	6.9	6.9	7.0	7.0	7.1	7.1	7.2
27	7.2	7.3	7.3	7.4	7.4	7.5	7.5	7.6	7.6	7.7	7.8	7.8	7.9	7.9	8.0	8.0
28	8.1	8.1	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.9
29	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.4	9.4	9.5	9.5	9.6	9.7	9.7	9.8
30	9.8	9.9	9.9	10.0	10.0	10.1	10.2	10.2	10.3	10.4	10.4	10.5	10.6	10.6	10.7	10.8
31	10.8	10.9	10.9	11.0	11.0	11.1	11.2	11.2	11.3	11.4	11.4	11.5	11.6	11.6	11.7	11.8
32	11.8	11.9	11.9	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.5	12.5	12.6	12.7	12.7	12.8
33	12.9	12.9	13.0	13.1	13.1	13.2	13.3	13.3	13.4	13.5	13.5	13.6	13.7	13.8	13.8	13.9
34	13.9	14.0	14.1	14.1	14.2	14.3	14.3	14.4	14.5	14.6	14.6	14.7	14.8	14.8	14.9	15.0
35	14.1	14.2	14.2	14.3	14.4	14.4	14.5	14.6	14.7	14.7	14.8	14.9	15.0	15.0	15.1	15.2
36	14.3	14.4	14.4	14.5	14.6	14.6	14.7	14.8	14.9	14.9	15.0	15.1	15.2	15.2	15.3	15.4
37	14.5	14.6	14.6	14.7	14.8	14.8	14.9	15.0	15.1	15.1	15.2	15.3	15.4	15.4	15.5	15.6
38	14.7	14.8	14.8	14.9	15.0	15.0	15.1	15.2	15.3	15.3	15.4	15.5	15.6	15.6	15.7	15.8
39	14.9	15.0	15.0	15.1	15.2	15.2	15.3	15.4	15.5	15.5	15.6	15.7	15.8	15.8	15.9	16.0
40	15.1	15.2	15.2	15.3	15.4	15.4	15.5	15.6	15.7	15.7	15.8	15.9	16.0	16.0	16.1	16.2
41	15.3	15.4	15.4	15.5	15.6	15.6	15.7	15.8	15.9	15.9	16.0	16.1	16.2	16.2	16.3	16.4
42	15.5	15.6	15.6	15.7	15.8	15.8	15.9	16.0	16.1	16.1	16.2	16.3	16.4	16.4	16.5	16.6
43	15.7	15.8	15.8	15.9	16.0	16.0	16.1	16.2	16.3	16.3	16.4	16.5	16.6	16.6	16.7	16.8
44	15.9	16.0	16.0	16.1	16.2	16.2	16.3	16.4	16.5	16.5	16.6	16.7	16.8	16.8	16.9	17.0
45	16.1	16.2	16.2	16.3	16.4	16.4	16.5	16.6	16.7	16.7	16.8	16.9	17.0	17.0	17.1	17.2
46	16.3	16.4	16.4	16.5	16.6	16.6	16.7	16.8	16.9	16.9	17.0	17.1	17.2	17.2	17.3	17.4
47	16.5	16.6	16.6	16.7	16.8	16.8	16.9	17.0	17.1	17.1	17.2	17.3	17.4	17.4	17.5	17.6
48	16.7	16.8	16.8	16.9	17.0	17.0	17.1	17.2	17.3	17.3	17.4	17.5	17.6	17.6	17.7	17.8
49	16.9	17.0	17.0	17.1	17.2	17.2	17.3	17.4	17.5	17.5	17.6	17.7	17.8	17.8	17.9	18.0
50	17.1	17.2	17.2	17.3	17.4	17.4	17.5	17.6	17.7	17.7	17.8	17.9	18.0	18.0	18.1	18.2
51	17.3	17.4	17.4	17.5	17.6	17.6	17.7	17.8	17.9	17.9	18.0	18.1	18.2	18.2	18.3	18.4
52	17.5	17.6	17.6	17.7	17.8	17.8	17.9	18.0	18.1	18.1	18.2	18.3	18.4	18.4	18.5	18.6
53	17.7	17.8	17.8	17.9	18.0	18.0	18.1	18.2	18.3	18.3	18.4	18.5	18.6	18.6	18.7	18.8
54	17.9	18.0	18.0	18.1	18.2	18.2	18.3	18.4	18.5	18.5	18.6	18.7	18.8	18.8	18.9	19.0
55	18.1	18.2	18.2	18.3	18.4	18.4	18.5	18.6	18.7	18.7	18.8	18.9	19.0	19.0	19.1	19.2
56	18.3	18.4	18.4	18.5	18.6	18.6	18.7	18.8	18.9	18.9	19.0	19.1	19.2	19.2	19.3	19.4
57	18.5	18.6	18.6	18.7	18.8	18.8	18.9	19.0	19.1	19.1	19.2	19.3	19.4	19.4	19.5	19.6
58	18.7	18.8	18.8	18.9	19.0	19.0	19.1	19.2	19.3	19.3	19.4	19.5	19.6	19.6	19.7	19.8
59	18.9	19.0	19.0	19.1	19.2	19.2	19.3	19.4	19.5	19.5	19.6	19.7	19.8	19.8	19.9	20.0
60	19.1	19.2	19.2	19.3	19.4	19.4	19.5	19.6	19.7	19.7	19.8	19.9	20.0	20.0	20.1	20.2

* 1KIP=1,000 POUNDS

Table 11.--Log weights for scaling lengths of 4 to 32 feet: density index = 38 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KIPS*) FOR DENSITY INDEX=38

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)														
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
6	.08	.09	.10	.12	.13	.14	.15	.16	.17	.18	.19	.20	.21	.22	.23
7	.11	.13	.15	.16	.18	.19	.21	.22	.24	.25	.26	.28	.29	.30	.31
8	.14	.17	.19	.21	.23	.25	.27	.29	.31	.33	.35	.36	.38	.40	.41
9	.18	.21	.24	.27	.29	.32	.34	.37	.39	.42	.44	.46	.48	.50	.52
10	.22	.26	.30	.33	.36	.39	.42	.45	.48	.51	.54	.57	.59	.62	.64
11	.27	.32	.36	.40	.44	.47	.51	.54	.58	.61	.65	.68	.72	.75	.78
12	.32	.38	.43	.48	.52	.56	.61	.65	.69	.73	.77	.81	.85	.89	.93
13	.38	.45	.51	.56	.62	.67	.72	.77	.82	.87	.92	.96	1.01	1.05	1.10
14	.45	.52	.59	.66	.72	.78	.84	.90	.96	1.01	1.07	1.12	1.17	1.23	1.28
15	.52	.61	.69	.76	.84	.91	.98	1.04	1.11	1.17	1.24	1.30	1.36	1.42	1.48
16	.60	.70	.79	.88	.96	1.04	1.12	1.20	1.27	1.35	1.42	1.49	1.56	1.63	1.70
17	.69	.80	.90	1.00	1.09	1.18	1.27	1.36	1.44	1.53	1.61	1.69	1.77	1.85	1.93
18	.78	.91	1.02	1.13	1.23	1.33	1.43	1.53	1.62	1.72	1.81	1.90	1.99	2.08	2.17
19	.88	1.02	1.15	1.27	1.38	1.49	1.60	1.71	1.82	1.92	2.02	2.12	2.22	2.32	2.42
20	.98	1.14	1.28	1.41	1.53	1.66	1.78	1.90	2.02	2.13	2.24	2.35	2.46	2.57	2.68
21	1.09	1.26	1.42	1.56	1.70	1.83	1.96	2.09	2.22	2.34	2.46	2.58	2.70	2.82	2.94
22	1.20	1.39	1.56	1.72	1.87	2.01	2.15	2.29	2.43	2.56	2.69	2.82	2.95	3.08	3.21
23	1.32	1.52	1.71	1.88	2.04	2.20	2.35	2.50	2.65	2.79	2.93	3.07	3.21	3.35	3.49
24	1.44	1.66	1.86	2.05	2.22	2.39	2.56	2.72	2.88	3.03	3.18	3.33	3.48	3.63	3.78
25	1.56	1.80	2.02	2.22	2.41	2.59	2.77	2.94	3.11	3.27	3.43	3.59	3.75	3.91	4.07
26	1.69	1.94	2.18	2.40	2.60	2.80	2.99	3.17	3.35	3.52	3.69	3.86	4.03	4.20	4.37
27	1.82	2.09	2.34	2.58	2.80	3.01	3.21	3.41	3.60	3.78	3.96	4.14	4.32	4.50	4.67
28	1.95	2.24	2.51	2.76	3.00	3.22	3.44	3.65	3.85	4.05	4.24	4.43	4.62	4.80	4.98
29	2.09	2.39	2.68	2.95	3.20	3.44	3.67	3.89	4.11	4.32	4.52	4.72	4.92	5.11	5.30
30	2.23	2.55	2.85	3.14	3.40	3.66	3.90	4.14	4.37	4.59	4.80	5.01	5.22	5.42	5.62
31	2.37	2.71	3.03	3.33	3.61	3.88	4.14	4.39	4.63	4.86	5.09	5.31	5.52	5.73	5.94
32	2.51	2.87	3.21	3.53	3.82	4.11	4.38	4.64	4.90	5.14	5.38	5.61	5.83	6.05	6.27
33	2.66	3.04	3.39	3.73	4.04	4.34	4.63	4.90	5.17	5.43	5.68	5.92	6.16	6.39	6.62
34	2.81	3.21	3.58	3.93	4.26	4.58	4.88	5.17	5.45	5.72	5.99	6.24	6.49	6.74	6.98
35	2.96	3.38	3.77	4.14	4.49	4.82	5.14	5.44	5.74	6.02	6.30	6.57	6.83	7.09	7.34
36	3.12	3.56	3.96	4.35	4.71	5.07	5.40	5.72	6.03	6.33	6.62	6.90	7.17	7.44	7.71
37	3.28	3.74	4.16	4.56	4.94	5.31	5.66	6.00	6.32	6.63	6.94	7.23	7.51	7.79	8.07
38	3.44	3.92	4.36	4.78	5.18	5.56	5.93	6.28	6.62	6.95	7.27	7.57	7.87	8.16	8.44
39	3.60	4.11	4.57	5.01	5.42	5.82	6.20	6.57	6.93	7.27	7.61	7.93	8.24	8.54	8.83
40	3.77	4.30	4.78	5.24	5.67	6.08	6.48	6.87	7.24	7.60	7.95	8.29	8.62	8.93	9.24
41	3.94	4.49	4.99	5.47	5.92	6.35	6.77	7.17	7.56	7.94	8.30	8.65	8.99	9.32	9.64
42	4.11	4.69	5.21	5.71	6.18	6.63	7.06	7.48	7.89	8.28	8.66	9.03	9.38	9.72	10.05
43	4.29	4.89	5.43	5.95	6.44	6.91	7.36	7.80	8.22	8.63	9.03	9.41	9.78	10.13	10.48
44	4.47	5.09	5.66	6.20	6.71	7.20	7.67	8.12	8.56	8.99	9.40	9.80	10.18	10.55	10.91
45	4.65	5.30	5.89	6.45	6.98	7.49	7.98	8.45	8.91	9.35	9.78	10.19	10.59	10.97	11.34
46	4.84	5.52	6.13	6.71	7.26	7.79	8.30	8.79	9.26	9.72	10.17	10.59	11.00	11.40	11.78
47	5.03	5.73	6.37	6.97	7.54	8.09	8.62	9.13	9.62	10.10	10.56	11.00	11.43	11.84	12.24
48	5.22	5.95	6.61	7.24	7.83	8.40	8.95	9.48	9.99	10.48	10.96	11.42	11.86	12.29	12.71
49	5.42	6.17	6.86	7.51	8.13	8.72	9.29	9.84	10.37	10.88	11.37	11.85	12.31	12.75	13.19
50	5.62	6.40	7.11	7.79	8.43	9.04	9.64	10.21	10.76	11.29	11.80	12.29	12.77	13.23	13.68
51	5.82	6.63	7.37	8.07	8.73	9.37	9.99	10.58	11.15	11.70	12.23	12.74	13.24	13.72	14.18
52	6.03	6.87	7.63	8.36	9.05	9.71	10.35	10.96	11.55	12.12	12.67	13.20	13.72	14.21	14.69
53	6.24	7.11	7.90	8.65	9.37	10.05	10.71	11.35	11.96	12.55	13.12	13.67	14.20	14.71	15.21
54	6.46	7.35	8.17	8.95	9.69	10.40	11.08	11.74	12.37	12.98	13.57	14.14	14.69	15.22	15.73
55	6.68	7.61	8.45	9.25	10.02	10.75	11.46	12.14	12.79	13.42	14.03	14.62	15.19	15.73	16.26
56	6.91	7.87	8.74	9.57	10.36	11.12	11.85	12.55	13.23	13.88	14.50	15.11	15.69	16.26	16.80
57	7.14	8.13	9.03	9.89	10.71	11.49	12.25	12.97	13.67	14.34	14.99	15.61	16.21	16.79	17.35
58	7.37	8.39	9.32	10.21	11.06	11.87	12.65	13.40	14.12	14.81	15.48	16.13	16.75	17.35	17.93
59	7.61	8.66	9.62	10.53	11.41	12.25	13.06	13.83	14.58	15.30	15.99	16.66	17.31	17.93	18.53
60	7.85	8.94	9.93	10.87	11.77	12.64	13.47	14.28	15.05	15.80	16.52	17.21	17.88	18.53	19.15
61	8.09	9.21	10.24	11.21	12.14	13.03	13.89	14.73	15.53	16.31	17.06	17.78	18.48	19.15	19.80
62	8.34	9.49	10.55	11.55	12.51	13.43	14.32	15.18	16.01	16.82	17.60	18.36	19.09	19.79	20.47
63	8.59	9.78	10.87	11.90	12.89	13.84	14.76	15.64	16.50	17.33	18.15	18.94	19.70	20.44	21.15
64	8.84	10.07	11.19	12.26	13.27	14.25	15.20	16.11	16.99	17.85	18.69	19.51	20.31	21.09	21.84
65	9.10	10.36	11.52	12.61	13.66	14.67	15.64	16.58	17.49	18.38	19.24	20.09	20.92	21.73	22.53
66	9.36	10.66	11.84	12.97	14.05	15.09	16.09	17.06	18.00	18.91	19.81	20.68	21.54	22.38	23.21
67	9.62	10.96	12.18	13.34	14.45	15.52	16.55	17.55	18.52	19.46	20.39	21.29	22.18	23.05	23.90
68	9.89	11.27	12.52	13.72	14.86	15.96	17.02	18.05	19.05	20.03	20.98	21.92	22.83	23.73	24.61
69	10.16	11.58	12.87	14.10	15.28	16.41	17.50	18.56	19.59	20.60	21.58	22.55	23.49	24.42	25.33
70	10.44	11.90	13.22	14.49	15.70	16.87	17.99	19.08	20.14	21.18	22.19	23.19	24.16	25.12	26.06
71	10.72	12.22	13.58	14.88	16.13	17.33	18.48	19.60	20.70	21.76	22.81	23.84	24.84	25.83	26.80
72	11.01	12.55	13.95	15.28	16.57	17.80	18.98	20.13	21.25	22.35	23.43	24.49	25.53	26.55	27.55
73	11.30	12.89	14.32	15.69	17.01	18.28	19.49	20.67	21.82	22.95	24.05	25.14	26.21	27.26	28.30
74	11.60	13.23	14.70	16.11	17.46	18.76	20.01	21.22	22.40	23.55	24.68	25.80	26.89	27.97	29.03
75	11.90	13.58	15.09	16.53	17.92	19.25	20.53	21.78	22.98	24.16	25.32	26.46	27.58	28.68	29.76
76	12.21	13.93	15.48	16.96	18.38	19.75	21.06	22.34	23.58	24.79	25.97	27.13	28.27	29.39	30.49
77	12.52	14.29	15.88	17.40	18.85	20.25	21.60	22.91	24.18	25.42	26.63	27.81	28.97	30.10	31.22
78	12.84	14.65	16.28	17.84	19.33	20.76	22.14	23.48	24.79	26.06	27.29	28.50	29.68	30.83	31.96
79	13.16	15.02	16.69	18.28	19.81	21.28	22.69	24.07	25.40	26.70	27.97	29.20	30.40	31.58	32.73
80	13.48	15.39	17.10	18.73	20.29	21.80	23.25	24.66	26.03	27.36	28.65	29.91	31.14	32.34	33.51

*1 KIP = 1,000 POUNDS

Table 12.--Log weights for scaling lengths of 34 to 60 feet: density index = 38 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KIPS*) FOR DENSITY INDEX=38

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	1	2	3	4	5	42	43	44	45	46	51	52	53	54	55	56
6	.11	.11	.11	.11	.11	.11	.11	.09	.09	.09	.09	.09	.07	.07	.07	.07
7	.17	.17	.17	.17	.17	.17	.16	.16	.16	.16	.15	.15	.14	.14	.13	.13
8	.24	.24	.24	.24	.24	.25	.25	.25	.25	.25	.24	.24	.24	.23	.23	.23
9	.34	.34	.34	.34	.34	.34	.34	.34	.34	.34	.34	.34	.34	.34	.34	.34
10	.46	.46	.46	.46	.46	.46	.46	.46	.46	.46	.46	.46	.46	.46	.46	.46
11	.61	.61	.61	.61	.61	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
12	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78
13	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
14	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
15	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
16	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76
17	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
18	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
19	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83
20	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26
21	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73
22	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23
23	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77
24	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35	5.35
25	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97
26	6.63	6.63	6.63	6.63	6.63	6.63	6.63	6.63	6.63	6.63	6.63	6.63	6.63	6.63	6.63	6.63
27	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33
28	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07
29	8.85	8.85	8.85	8.85	8.85	8.85	8.85	8.85	8.85	8.85	8.85	8.85	8.85	8.85	8.85	8.85
30	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67
31	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53
32	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43
33	12.37	12.37	12.37	12.37	12.37	12.37	12.37	12.37	12.37	12.37	12.37	12.37	12.37	12.37	12.37	12.37
34	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35
35	14.37	14.37	14.37	14.37	14.37	14.37	14.37	14.37	14.37	14.37	14.37	14.37	14.37	14.37	14.37	14.37
36	15.43	15.43	15.43	15.43	15.43	15.43	15.43	15.43	15.43	15.43	15.43	15.43	15.43	15.43	15.43	15.43
37	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53
38	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67
39	18.85	18.85	18.85	18.85	18.85	18.85	18.85	18.85	18.85	18.85	18.85	18.85	18.85	18.85	18.85	18.85
40	20.07	20.07	20.07	20.07	20.07	20.07	20.07	20.07	20.07	20.07	20.07	20.07	20.07	20.07	20.07	20.07
41	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33
42	22.63	22.63	22.63	22.63	22.63	22.63	22.63	22.63	22.63	22.63	22.63	22.63	22.63	22.63	22.63	22.63
43	23.97	23.97	23.97	23.97	23.97	23.97	23.97	23.97	23.97	23.97	23.97	23.97	23.97	23.97	23.97	23.97
44	25.35	25.35	25.35	25.35	25.35	25.35	25.35	25.35	25.35	25.35	25.35	25.35	25.35	25.35	25.35	25.35
45	26.77	26.77	26.77	26.77	26.77	26.77	26.77	26.77	26.77	26.77	26.77	26.77	26.77	26.77	26.77	26.77
46	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23
47	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73
48	31.27	31.27	31.27	31.27	31.27	31.27	31.27	31.27	31.27	31.27	31.27	31.27	31.27	31.27	31.27	31.27
49	32.85	32.85	32.85	32.85	32.85	32.85	32.85	32.85	32.85	32.85	32.85	32.85	32.85	32.85	32.85	32.85
50	34.47	34.47	34.47	34.47	34.47	34.47	34.47	34.47	34.47	34.47	34.47	34.47	34.47	34.47	34.47	34.47
51	36.13	36.13	36.13	36.13	36.13	36.13	36.13	36.13	36.13	36.13	36.13	36.13	36.13	36.13	36.13	36.13
52	37.83	37.83	37.83	37.83	37.83	37.83	37.83	37.83	37.83	37.83	37.83	37.83	37.83	37.83	37.83	37.83
53	39.57	39.57	39.57	39.57	39.57	39.57	39.57	39.57	39.57	39.57	39.57	39.57	39.57	39.57	39.57	39.57
54	41.35	41.35	41.35	41.35	41.35	41.35	41.35	41.35	41.35	41.35	41.35	41.35	41.35	41.35	41.35	41.35
55	43.17	43.17	43.17	43.17	43.17	43.17	43.17	43.17	43.17	43.17	43.17	43.17	43.17	43.17	43.17	43.17
56	45.03	45.03	45.03	45.03	45.03	45.03	45.03	45.03	45.03	45.03	45.03	45.03	45.03	45.03	45.03	45.03
57	46.93	46.93	46.93	46.93	46.93	46.93	46.93	46.93	46.93	46.93	46.93	46.93	46.93	46.93	46.93	46.93
58	48.87	48.87	48.87	48.87	48.87	48.87	48.87	48.87	48.87	48.87	48.87	48.87	48.87	48.87	48.87	48.87
59	50.85	50.85	50.85	50.85	50.85	50.85	50.85	50.85	50.85	50.85	50.85	50.85	50.85	50.85	50.85	50.85
60	52.87	52.87	52.87	52.87	52.87	52.87	52.87	52.87	52.87	52.87	52.87	52.87	52.87	52.87	52.87	52.87

* 1KIP=1 00 POUNDS

Table 13.--Log weights for scaling lengths of 4 to 32 feet: density index = 40 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KIPS*) FOR DENSITY INDEX=40

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
6	.06	.08	.09	.10	.11	.12	.13	.14	.15	.16	.17	.18	.19	.20	.21
7	.08	.11	.13	.15	.16	.18	.19	.21	.22	.24	.25	.26	.28	.29	.30
8	.11	.15	.18	.20	.22	.24	.26	.28	.30	.32	.34	.36	.38	.40	.42
9	.14	.19	.23	.26	.29	.31	.34	.37	.39	.42	.44	.47	.49	.52	.54
10	.17	.24	.29	.33	.36	.39	.43	.46	.49	.52	.55	.58	.61	.64	.67
11	.21	.29	.35	.40	.44	.48	.52	.56	.59	.63	.67	.71	.74	.78	.82
12	.25	.34	.42	.48	.53	.57	.62	.67	.71	.76	.80	.85	.89	.94	.98
13	.29	.40	.49	.56	.62	.67	.73	.78	.83	.89	.94	.99	1.04	1.09	1.15
14	.33	.46	.57	.65	.71	.77	.84	.90	.96	1.02	1.08	1.14	1.20	1.26	1.32
15	.38	.53	.65	.74	.82	.89	.96	1.03	1.10	1.17	1.23	1.30	1.37	1.44	1.50
16	.43	.60	.73	.84	.93	1.01	1.09	1.17	1.24	1.32	1.39	1.47	1.54	1.62	1.69
17	.48	.67	.82	.94	1.04	1.13	1.22	1.31	1.39	1.47	1.56	1.64	1.72	1.81	1.89
18	.53	.74	.91	1.04	1.16	1.26	1.36	1.45	1.54	1.64	1.73	1.82	1.91	2.00	2.09
19	.59	.82	1.00	1.16	1.28	1.40	1.50	1.61	1.71	1.81	1.91	2.01	2.11	2.21	2.31
20	.65	.91	1.11	1.28	1.42	1.54	1.66	1.77	1.88	1.99	2.10	2.21	2.32	2.43	2.54
21	.71	1.00	1.22	1.40	1.56	1.69	1.82	1.94	2.06	2.18	2.30	2.42	2.54	2.66	2.78
22	.78	1.09	1.33	1.53	1.70	1.85	1.99	2.12	2.25	2.38	2.51	2.64	2.77	2.90	3.03
23	.84	1.18	1.44	1.66	1.85	2.01	2.16	2.30	2.44	2.58	2.72	2.86	3.00	3.14	3.28
24	.91	1.27	1.56	1.79	1.99	2.17	2.33	2.48	2.63	2.78	2.93	3.08	3.23	3.38	3.53
25	.98	1.37	1.67	1.93	2.14	2.33	2.50	2.67	2.83	2.99	3.15	3.31	3.47	3.63	3.79
26	1.05	1.47	1.79	2.06	2.30	2.50	2.68	2.86	3.03	3.20	3.37	3.54	3.71	3.88	4.05
27	1.12	1.56	1.91	2.20	2.45	2.67	2.86	3.05	3.23	3.41	3.59	3.77	3.95	4.13	4.31
28	1.19	1.66	2.03	2.34	2.61	2.84	3.04	3.24	3.43	3.62	3.81	4.00	4.19	4.38	4.57
29	1.26	1.76	2.15	2.48	2.76	3.01	3.22	3.43	3.63	3.83	4.03	4.23	4.43	4.63	4.83
30	1.33	1.86	2.27	2.62	2.92	3.18	3.40	3.62	3.83	4.04	4.25	4.46	4.67	4.88	5.09
31	1.40	1.96	2.39	2.76	3.08	3.35	3.59	3.81	4.03	4.25	4.47	4.69	4.91	5.13	5.35
32	1.47	2.06	2.51	2.90	3.23	3.52	3.77	4.00	4.23	4.46	4.69	4.92	5.15	5.38	5.61
33	1.54	2.16	2.63	3.04	3.39	3.69	3.95	4.19	4.43	4.67	4.91	5.15	5.39	5.63	5.87
34	1.61	2.26	2.75	3.18	3.54	3.86	4.13	4.38	4.63	4.88	5.13	5.38	5.63	5.88	6.13
35	1.68	2.36	2.87	3.32	3.70	4.03	4.31	4.57	4.83	5.09	5.35	5.61	5.87	6.13	6.39
36	1.75	2.46	2.99	3.46	3.85	4.20	4.49	4.76	5.03	5.30	5.57	5.84	6.11	6.38	6.65
37	1.82	2.56	3.11	3.60	4.01	4.37	4.67	4.95	5.23	5.51	5.79	6.07	6.35	6.63	6.91
38	1.89	2.66	3.23	3.74	4.16	4.54	4.85	5.14	5.43	5.72	6.01	6.30	6.59	6.88	7.17
39	1.96	2.76	3.35	3.88	4.32	4.71	5.03	5.33	5.63	5.93	6.23	6.53	6.83	7.13	7.43
40	2.03	2.86	3.47	4.02	4.47	4.88	5.21	5.52	5.83	6.14	6.45	6.76	7.07	7.38	7.69
41	2.10	2.96	3.59	4.16	4.63	5.05	5.39	5.71	6.03	6.35	6.67	6.99	7.31	7.63	7.95
42	2.17	3.06	3.71	4.30	4.78	5.22	5.57	5.90	6.23	6.56	6.89	7.22	7.55	7.88	8.21
43	2.24	3.16	3.83	4.44	4.94	5.39	5.75	6.09	6.43	6.77	7.11	7.45	7.79	8.13	8.47
44	2.31	3.26	3.95	4.58	5.09	5.56	5.93	6.28	6.63	6.98	7.33	7.68	8.03	8.38	8.73
45	2.38	3.36	4.07	4.72	5.25	5.73	6.11	6.47	6.83	7.19	7.55	7.91	8.27	8.63	8.99
46	2.45	3.46	4.19	4.86	5.40	5.90	6.29	6.66	7.03	7.40	7.77	8.14	8.51	8.88	9.25
47	2.52	3.56	4.31	5.00	5.56	6.07	6.47	6.85	7.23	7.61	7.99	8.37	8.75	9.13	9.51
48	2.59	3.66	4.43	5.14	5.71	6.24	6.65	7.04	7.43	7.82	8.21	8.60	8.99	9.38	9.77
49	2.66	3.76	4.55	5.28	5.87	6.41	6.83	7.23	7.63	8.03	8.43	8.83	9.23	9.63	10.03
50	2.73	3.86	4.67	5.42	6.02	6.58	7.01	7.42	7.83	8.24	8.65	9.06	9.47	9.88	10.29
51	2.80	3.96	4.79	5.56	6.18	6.75	7.19	7.61	8.03	8.45	8.87	9.29	9.71	10.13	10.55
52	2.87	4.06	4.91	5.70	6.33	6.92	7.37	7.80	8.23	8.66	9.09	9.52	9.95	10.38	10.81
53	2.94	4.16	5.03	5.84	6.49	7.09	7.55	7.99	8.43	8.87	9.31	9.75	10.19	10.63	11.07
54	3.01	4.26	5.15	5.98	6.64	7.26	7.73	8.18	8.63	9.08	9.53	9.98	10.43	10.88	11.33
55	3.08	4.36	5.27	6.12	6.80	7.43	7.91	8.37	8.83	9.29	9.75	10.21	10.67	11.13	11.59
56	3.15	4.46	5.39	6.26	6.95	7.60	8.09	8.56	9.03	9.50	9.97	10.44	10.91	11.38	11.85
57	3.22	4.56	5.51	6.40	7.11	7.77	8.27	8.75	9.23	9.71	10.19	10.67	11.15	11.63	12.11
58	3.29	4.66	5.63	6.54	7.26	7.94	8.45	8.94	9.43	9.92	10.41	10.90	11.39	11.88	12.37
59	3.36	4.76	5.75	6.68	7.42	8.11	8.63	9.13	9.63	10.13	10.63	11.13	11.63	12.13	12.63
60	3.43	4.86	5.87	6.82	7.57	8.28	8.81	9.32	9.83	10.34	10.85	11.36	11.87	12.38	12.89

* (KIPS)

Table 14.--Log weights for scaling lengths of 34 to 60 feet: density index - 40 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

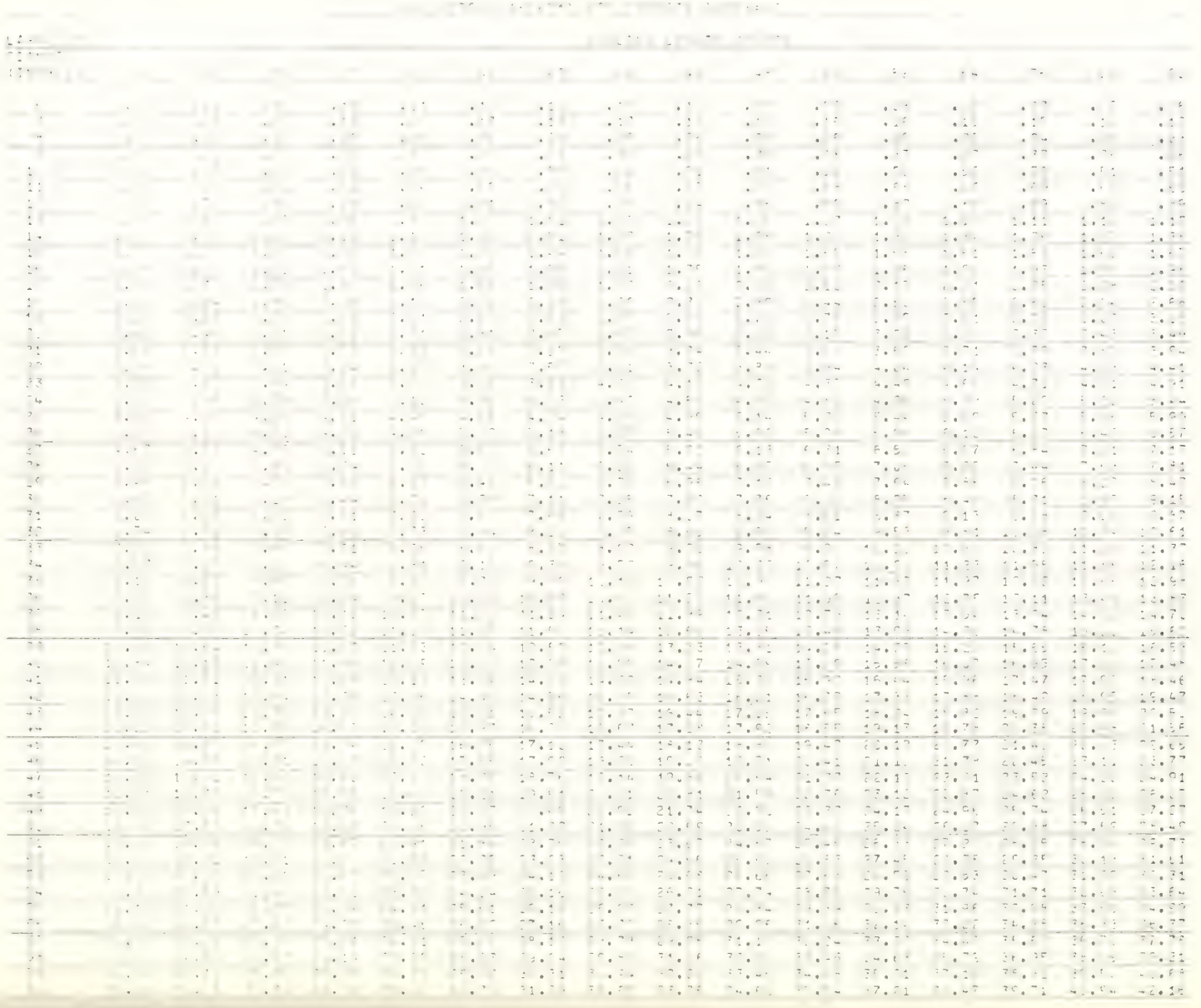


Table 15.--Log weights for scaling lengths of 4 to 32 feet: density index = 42 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

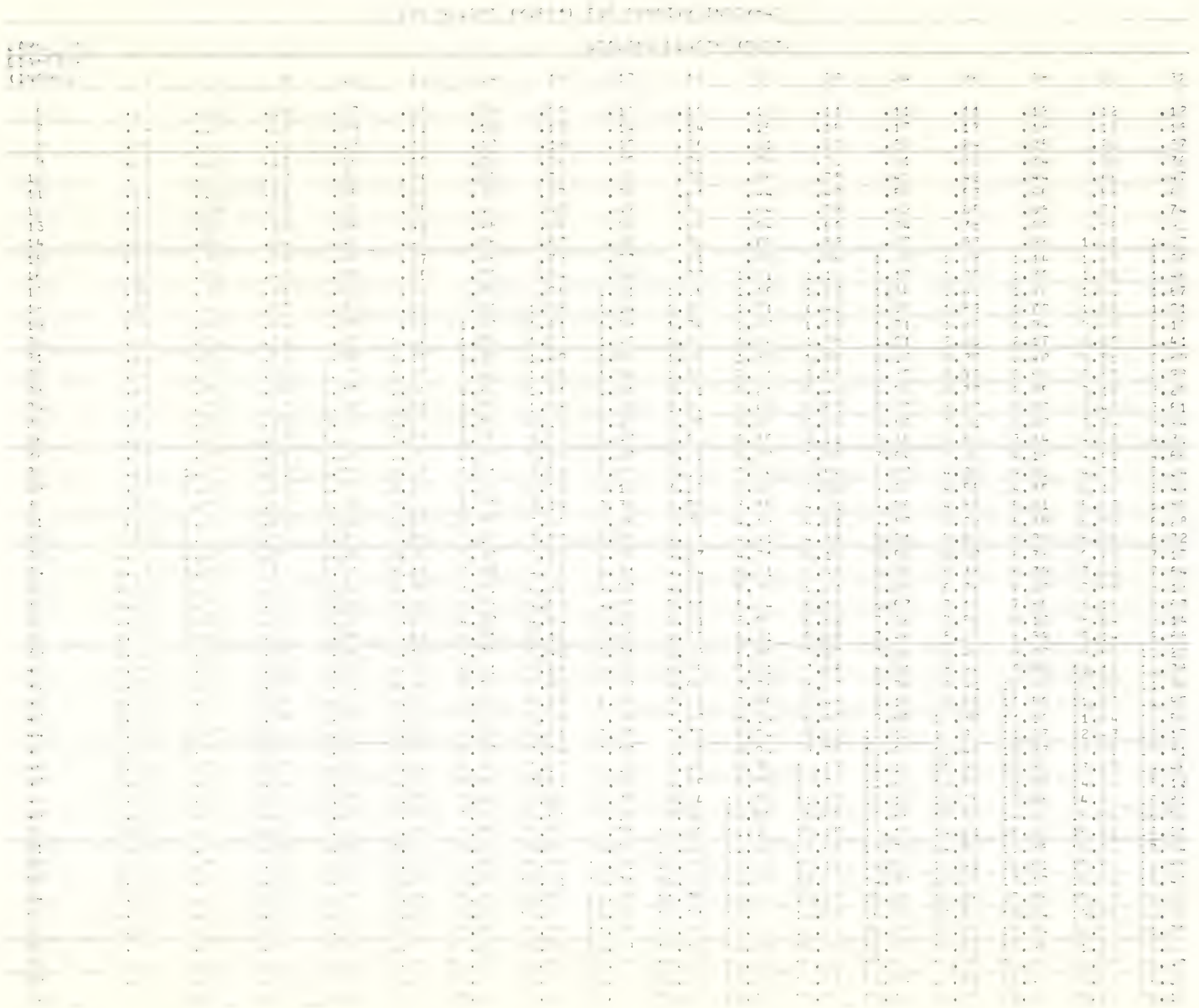


Table 16.--Log weights for scaling lengths of 34 to 60 feet: density index - 42 pounds per cubic foot

[Assumed taper of 1 inch per 5 feet, trim allowance of 1 inch per 4 feet]

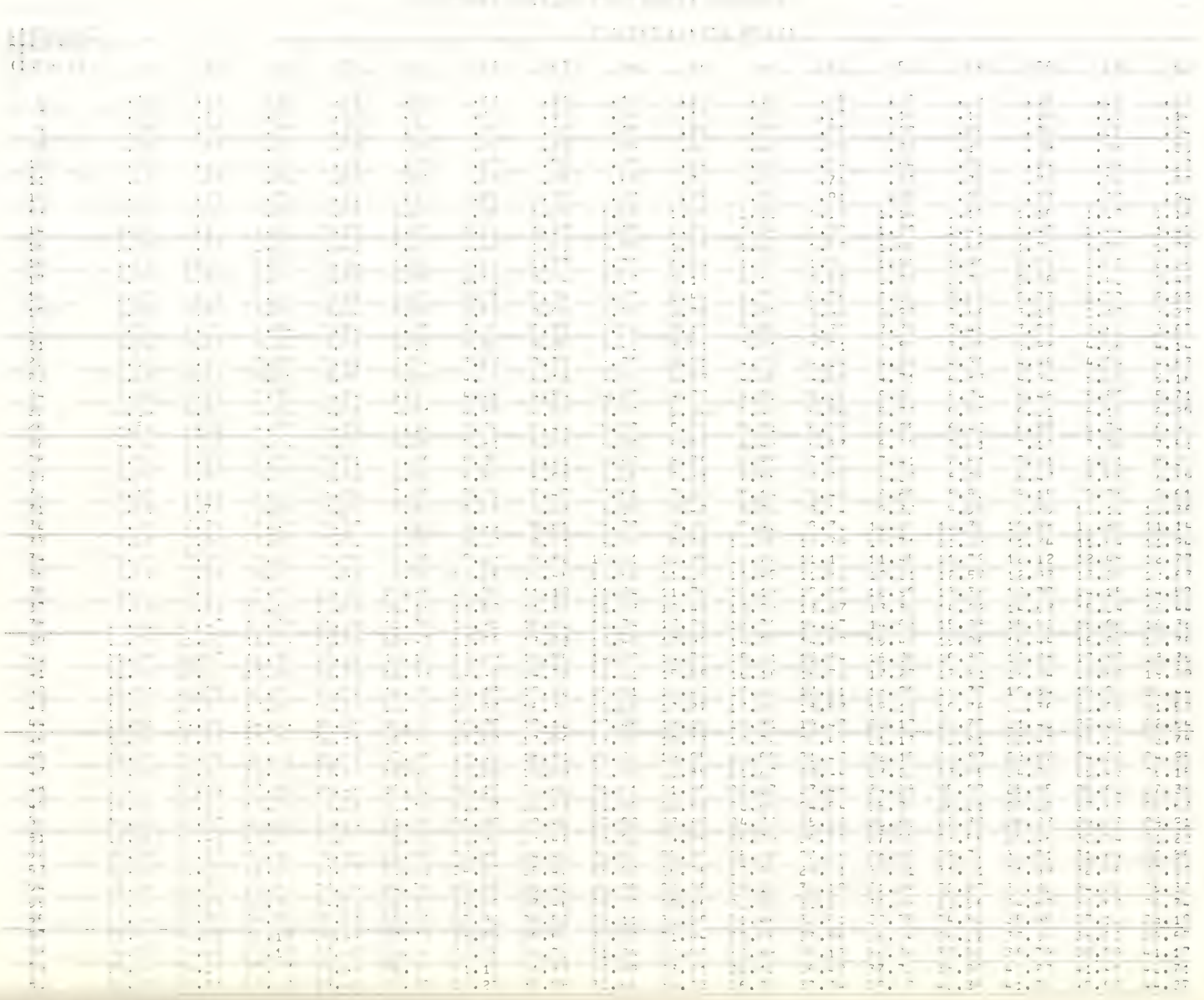


Table 17.--Log weights for scaling lengths of 4 to 32 feet: density index = 44 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (METRIC*) FOR DENSITY INDEX=44

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
6	.07	.09	.09	.09	.09	.09	.10	.10	.10	.11	.11	.12	.12	.12	.12	.12
7	.09	.11	.11	.11	.12	.13	.14	.14	.15	.15	.16	.17	.17	.18	.18	.19
8	.11	.13	.14	.15	.16	.17	.18	.19	.20	.21	.22	.23	.24	.25	.26	.27
9	.13	.16	.17	.18	.19	.21	.22	.23	.24	.25	.26	.28	.29	.30	.31	.32
10	.15	.18	.20	.21	.23	.25	.26	.27	.28	.30	.31	.32	.33	.34	.35	.36
11	.18	.21	.23	.25	.27	.29	.30	.32	.33	.34	.36	.37	.38	.39	.40	.41
12	.20	.24	.26	.28	.30	.32	.34	.36	.37	.39	.40	.42	.43	.44	.45	.46
13	.23	.27	.29	.32	.34	.36	.38	.40	.42	.43	.45	.47	.48	.49	.51	.52
14	.25	.30	.33	.35	.38	.40	.42	.44	.46	.48	.50	.52	.53	.55	.56	.58
15	.28	.33	.36	.39	.42	.44	.46	.49	.51	.53	.55	.57	.59	.60	.62	.63
16	.31	.36	.40	.43	.46	.48	.51	.53	.56	.58	.60	.62	.64	.66	.68	.69
17	.34	.40	.43	.47	.50	.53	.56	.58	.61	.63	.65	.68	.70	.72	.74	.75
18	.37	.43	.47	.51	.54	.57	.60	.63	.66	.68	.71	.73	.75	.78	.80	.82
19	.40	.47	.51	.55	.58	.62	.65	.68	.71	.73	.76	.79	.81	.83	.86	.88
20	.43	.50	.55	.59	.63	.66	.70	.73	.76	.79	.82	.84	.87	.89	.92	.94
21	.46	.54	.59	.63	.67	.71	.75	.78	.81	.84	.87	.90	.93	.95	.98	1.00
22	.49	.57	.63	.67	.72	.76	.80	.83	.86	.90	.93	.96	.99	1.01	1.04	1.07
23	.52	.61	.67	.72	.76	.81	.85	.88	.92	.95	.98	1.02	1.05	1.08	1.11	1.13
24	.55	.64	.71	.76	.81	.85	.89	.93	.97	1.00	1.04	1.07	1.11	1.14	1.17	1.20
25	.58	.68	.75	.80	.85	.90	.94	.98	1.02	1.06	1.09	1.13	1.17	1.20	1.23	1.26
26	.61	.72	.79	.84	.90	.94	.99	1.03	1.07	1.11	1.15	1.19	1.23	1.26	1.29	1.33
27	.64	.75	.83	.89	.94	.99	1.04	1.08	1.12	1.17	1.21	1.25	1.29	1.32	1.36	1.39
28	.67	.79	.87	.93	.98	1.04	1.09	1.13	1.18	1.22	1.26	1.31	1.35	1.38	1.42	1.46
29	.71	.83	.91	.97	1.03	1.08	1.13	1.18	1.23	1.27	1.32	1.36	1.40	1.44	1.48	1.52
30	.74	.87	.95	1.01	1.07	1.13	1.18	1.23	1.28	1.33	1.37	1.42	1.46	1.50	1.54	1.58
31	.77	.91	1.00	1.06	1.12	1.17	1.23	1.28	1.33	1.38	1.43	1.48	1.52	1.56	1.60	1.64
32	.80	.95	1.04	1.10	1.16	1.22	1.27	1.33	1.38	1.43	1.48	1.53	1.58	1.62	1.67	1.71
33	.83	.99	1.08	1.14	1.21	1.26	1.32	1.38	1.43	1.48	1.54	1.59	1.64	1.68	1.73	1.77
34	.87	1.03	1.12	1.19	1.25	1.31	1.37	1.43	1.48	1.54	1.59	1.64	1.70	1.74	1.79	1.84
35	.90	1.07	1.16	1.23	1.30	1.36	1.42	1.48	1.54	1.59	1.65	1.70	1.76	1.81	1.86	1.90
36	.94	1.11	1.21	1.28	1.34	1.41	1.47	1.53	1.59	1.65	1.71	1.76	1.82	1.87	1.92	1.97
37	.97	1.15	1.25	1.32	1.39	1.46	1.52	1.59	1.65	1.71	1.76	1.82	1.88	1.93	1.99	2.04
38	1.01	1.19	1.29	1.37	1.44	1.51	1.58	1.64	1.70	1.76	1.82	1.88	1.94	2.00	2.05	2.11
39	1.04	1.23	1.34	1.41	1.49	1.56	1.63	1.69	1.76	1.82	1.88	1.94	2.00	2.06	2.12	2.17
40	1.08	1.27	1.38	1.46	1.54	1.61	1.68	1.75	1.81	1.88	1.94	2.00	2.06	2.12	2.18	2.24
41	1.11	1.31	1.42	1.51	1.59	1.66	1.73	1.80	1.87	1.93	2.00	2.06	2.12	2.18	2.25	2.31
42	1.15	1.35	1.47	1.55	1.63	1.71	1.78	1.85	1.92	1.99	2.05	2.12	2.18	2.25	2.31	2.37
43	1.18	1.39	1.51	1.60	1.68	1.76	1.84	1.91	1.98	2.04	2.11	2.18	2.24	2.31	2.37	2.44
44	1.22	1.43	1.56	1.65	1.73	1.81	1.89	1.96	2.03	2.10	2.17	2.24	2.30	2.37	2.44	2.50
45	1.25	1.47	1.60	1.69	1.78	1.86	1.94	2.01	2.09	2.16	2.23	2.30	2.36	2.43	2.50	2.57
46	1.29	1.51	1.64	1.74	1.83	1.91	1.99	2.07	2.14	2.21	2.28	2.35	2.42	2.49	2.56	2.63
47	1.32	1.55	1.69	1.78	1.87	1.96	2.04	2.12	2.19	2.27	2.34	2.41	2.48	2.55	2.62	2.69
48	1.36	1.59	1.73	1.83	1.92	2.01	2.09	2.17	2.25	2.32	2.40	2.47	2.54	2.61	2.68	2.75
49	1.39	1.63	1.77	1.87	1.97	2.06	2.14	2.22	2.30	2.38	2.45	2.53	2.60	2.67	2.74	2.81
50	1.43	1.67	1.82	1.92	2.02	2.11	2.19	2.28	2.36	2.43	2.51	2.59	2.66	2.73	2.81	2.88
51	1.46	1.71	1.86	1.97	2.07	2.16	2.25	2.33	2.41	2.49	2.57	2.64	2.72	2.79	2.87	2.94
52	1.50	1.75	1.90	2.01	2.11	2.21	2.30	2.38	2.47	2.55	2.62	2.70	2.78	2.85	2.93	3.00
53	1.53	1.79	1.95	2.06	2.16	2.26	2.35	2.44	2.52	2.60	2.68	2.76	2.84	2.91	2.99	3.06
54	1.57	1.83	1.99	2.10	2.21	2.31	2.40	2.49	2.58	2.66	2.74	2.82	2.90	2.97	3.05	3.12
55	1.60	1.87	2.03	2.15	2.25	2.36	2.45	2.54	2.63	2.72	2.80	2.88	2.96	3.03	3.11	3.18
56	1.64	1.91	2.08	2.19	2.30	2.41	2.50	2.60	2.69	2.77	2.86	2.94	3.02	3.09	3.17	3.24
57	1.67	1.95	2.12	2.24	2.35	2.46	2.56	2.65	2.74	2.83	2.91	3.00	3.08	3.15	3.23	3.30
58	1.71	1.99	2.16	2.28	2.39	2.51	2.61	2.70	2.80	2.89	2.97	3.06	3.14	3.21	3.29	3.36
59	1.74	2.03	2.20	2.33	2.44	2.56	2.66	2.76	2.85	2.94	3.03	3.12	3.20	3.27	3.35	3.42
60	1.78	2.07	2.25	2.37	2.49	2.61	2.71	2.81	2.91	3.00	3.09	3.18	3.26	3.33	3.41	3.48

* METRIC TONS

Table 18.--Log weights for scaling lengths of 34 to 60 feet: density index = 44 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

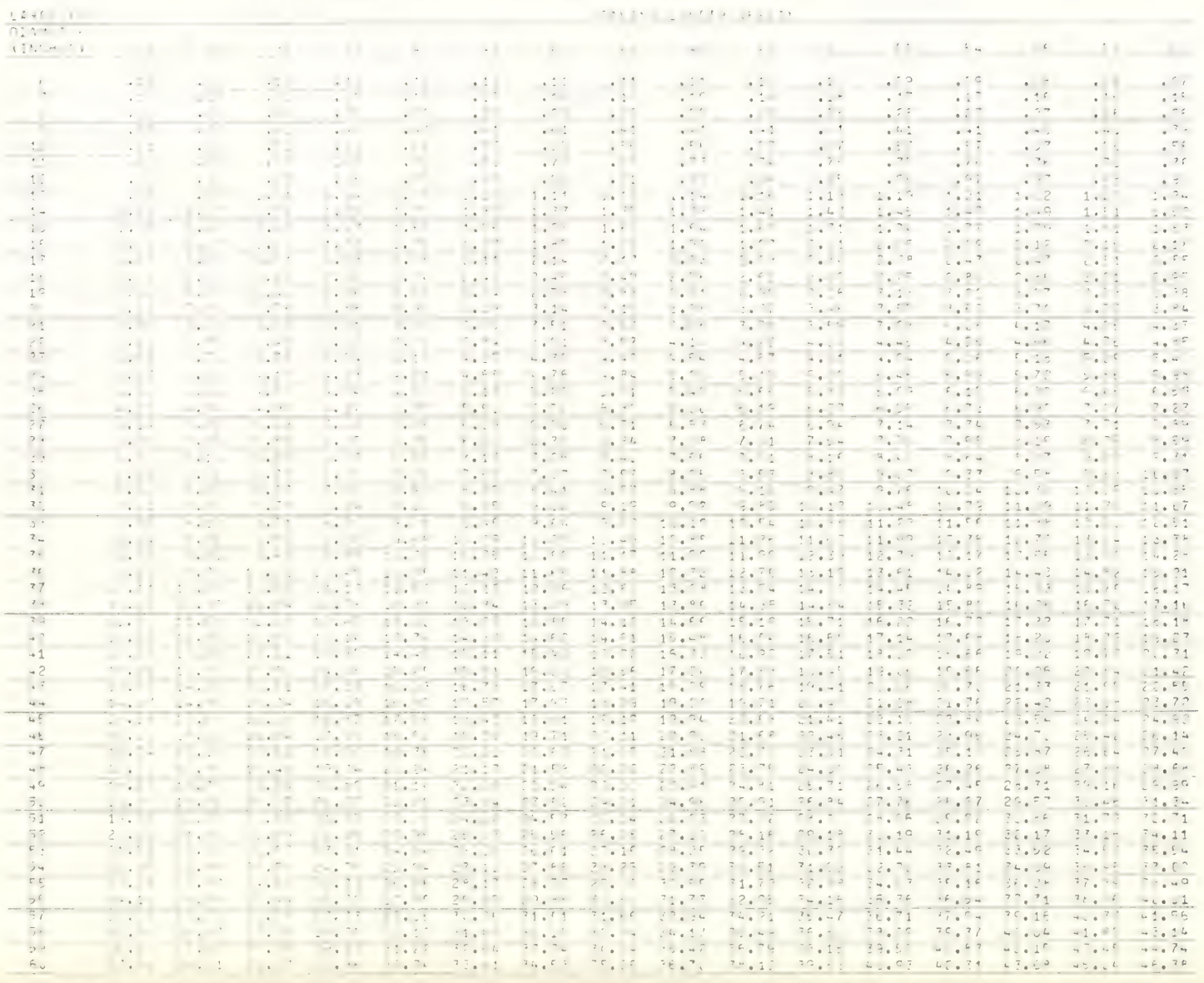


Table 19.--Log weights for scaling lengths of 4 to 32 feet: density index = 46 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (POUNDS) FOR DENSITY INDEX=46

LARGE-END DIAM. (INCHES)	SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
6	.07	.09	.10	.11	.11	.11	.11	.12	.12	.13	.13	.13	.13	.13	.13
7	.11	.13	.14	.15	.15	.16	.17	.18	.19	.19	.20	.20	.21	.21	.22
8	.14	.17	.19	.20	.21	.22	.23	.24	.25	.26	.27	.28	.28	.29	.29
9	.18	.22	.24	.26	.27	.28	.29	.31	.32	.33	.34	.35	.36	.37	.38
10	.23	.27	.30	.32	.34	.35	.36	.38	.39	.41	.42	.43	.44	.45	.46
11	.28	.33	.37	.39	.41	.43	.45	.46	.48	.50	.52	.53	.54	.55	.56
12	.33	.39	.44	.46	.48	.51	.53	.55	.57	.59	.61	.62	.63	.64	.66
13	.38	.46	.51	.54	.56	.59	.62	.64	.66	.68	.71	.72	.73	.75	.76
14	.44	.53	.59	.62	.65	.68	.71	.73	.76	.78	.81	.83	.84	.86	.87
15	.50	.60	.67	.71	.74	.77	.80	.83	.86	.89	.92	.94	.96	.98	.99
16	.57	.68	.76	.80	.84	.87	.91	.94	.97	1.00	1.03	1.06	1.08	1.10	1.12
17	.64	.76	.85	.90	.94	.98	1.02	1.05	1.09	1.12	1.16	1.19	1.21	1.23	1.26
18	.71	.85	.94	1.00	1.04	1.09	1.13	1.17	1.21	1.25	1.29	1.32	1.35	1.37	1.40
19	.79	.94	1.04	1.10	1.15	1.20	1.25	1.29	1.33	1.38	1.42	1.46	1.49	1.51	1.54
20	.87	1.03	1.14	1.21	1.26	1.32	1.37	1.41	1.46	1.51	1.56	1.60	1.63	1.66	1.69
21	.95	1.13	1.25	1.32	1.38	1.44	1.49	1.54	1.59	1.64	1.69	1.74	1.78	1.81	1.84
22	1.04	1.23	1.36	1.44	1.50	1.56	1.62	1.67	1.73	1.78	1.84	1.89	1.93	1.96	2.00
23	1.13	1.33	1.47	1.56	1.62	1.69	1.75	1.81	1.87	1.93	1.99	2.04	2.08	2.12	2.16
24	1.22	1.44	1.59	1.68	1.75	1.82	1.89	1.95	2.01	2.08	2.14	2.20	2.24	2.28	2.32
25	1.31	1.55	1.71	1.81	1.88	1.96	2.03	2.10	2.16	2.23	2.30	2.36	2.41	2.45	2.49
26	1.41	1.66	1.83	1.94	2.02	2.10	2.17	2.24	2.31	2.39	2.46	2.52	2.57	2.62	2.66
27	1.51	1.77	1.96	2.07	2.15	2.24	2.32	2.39	2.47	2.54	2.62	2.69	2.74	2.79	2.84
28	1.61	1.89	2.08	2.20	2.29	2.38	2.46	2.54	2.62	2.70	2.78	2.85	2.91	2.96	3.01
29	1.71	2.00	2.21	2.33	2.42	2.52	2.61	2.69	2.77	2.86	2.94	3.01	3.08	3.13	3.18
30	1.81	2.12	2.33	2.47	2.57	2.66	2.75	2.84	2.93	3.02	3.10	3.18	3.25	3.30	3.36
31	1.92	2.24	2.47	2.60	2.71	2.81	2.90	2.99	3.09	3.18	3.27	3.35	3.42	3.48	3.53
32	2.03	2.36	2.60	2.74	2.85	2.95	3.05	3.15	3.25	3.34	3.43	3.52	3.59	3.65	3.71
33	2.14	2.49	2.74	2.88	3.00	3.10	3.21	3.31	3.41	3.51	3.60	3.69	3.77	3.83	3.89
34	2.25	2.62	2.87	3.03	3.15	3.26	3.37	3.47	3.58	3.68	3.78	3.87	3.95	4.02	4.08
35	2.36	2.75	3.01	3.17	3.30	3.42	3.53	3.64	3.75	3.85	3.96	4.05	4.14	4.21	4.28
36	2.48	2.88	3.16	3.32	3.45	3.58	3.69	3.81	3.92	4.03	4.14	4.24	4.33	4.41	4.48
37	2.60	3.02	3.30	3.48	3.61	3.74	3.86	3.98	4.10	4.21	4.32	4.43	4.53	4.61	4.68
38	2.72	3.16	3.45	3.63	3.77	3.90	4.03	4.15	4.28	4.39	4.51	4.62	4.72	4.81	4.89
39	2.84	3.30	3.60	3.79	3.93	4.07	4.20	4.33	4.46	4.58	4.70	4.81	4.92	5.01	5.09
40	2.96	3.44	3.75	3.95	4.10	4.24	4.38	4.51	4.64	4.77	4.89	5.01	5.12	5.21	5.30
41	3.08	3.58	3.91	4.11	4.26	4.41	4.55	4.69	4.83	4.96	5.09	5.21	5.32	5.42	5.51
42	3.21	3.72	4.06	4.27	4.43	4.58	4.73	4.87	5.01	5.15	5.28	5.41	5.53	5.63	5.72
43	3.33	3.86	4.21	4.43	4.59	4.75	4.90	5.05	5.20	5.34	5.48	5.61	5.73	5.84	5.94
44	3.46	4.00	4.37	4.59	4.76	4.92	5.08	5.23	5.38	5.53	5.68	5.81	5.94	6.05	6.15
45	3.59	4.15	4.52	4.76	4.93	5.10	5.26	5.42	5.57	5.73	5.88	6.02	6.15	6.27	6.37
46	3.72	4.30	4.69	4.93	5.11	5.28	5.45	5.61	5.77	5.93	6.08	6.23	6.37	6.49	6.60
47	3.85	4.45	4.85	5.10	5.29	5.47	5.64	5.81	5.97	6.13	6.29	6.44	6.58	6.71	6.83
48	3.98	4.60	5.02	5.28	5.47	5.66	5.84	6.01	6.18	6.34	6.50	6.66	6.80	6.94	7.06
49	4.12	4.76	5.19	5.46	5.66	5.85	6.04	6.22	6.39	6.56	6.72	6.88	7.03	7.17	7.30
50	4.26	4.92	5.36	5.64	5.85	6.05	6.24	6.42	6.60	6.77	6.94	7.10	7.25	7.40	7.53
51	4.40	5.08	5.54	5.83	6.04	6.25	6.44	6.63	6.81	6.99	7.16	7.33	7.48	7.63	7.77
52	4.54	5.24	5.71	6.02	6.24	6.45	6.65	6.84	7.03	7.21	7.39	7.56	7.72	7.87	8.01
53	4.68	5.40	5.89	6.20	6.43	6.65	6.86	7.06	7.25	7.44	7.62	7.80	7.96	8.12	8.26
54	4.82	5.57	6.07	6.39	6.63	6.86	7.07	7.28	7.48	7.67	7.86	8.04	8.21	8.37	8.52
55	4.97	5.73	6.25	6.58	6.83	7.06	7.29	7.50	7.71	7.91	8.10	8.28	8.46	8.62	8.78
56	5.12	5.90	6.43	6.77	7.03	7.27	7.50	7.72	7.93	8.14	8.34	8.53	8.71	8.88	9.04
57	5.27	6.07	6.62	6.97	7.23	7.48	7.72	7.94	8.16	8.37	8.58	8.78	8.96	9.14	9.30
58	5.42	6.24	6.80	7.17	7.44	7.69	7.93	8.17	8.39	8.61	8.82	9.03	9.22	9.40	9.57
59	5.57	6.41	6.99	7.36	7.64	7.90	8.15	8.39	8.62	8.85	9.07	9.28	9.48	9.67	9.84
60	5.72	6.59	7.18	7.56	7.85	8.11	8.37	8.62	8.86	9.09	9.32	9.54	9.74	9.93	10.11
61	5.88	6.77	7.38	7.77	8.06	8.33	8.59	8.85	9.09	9.34	9.57	9.79	10.00	10.20	10.38
62	6.04	6.95	7.58	7.98	8.28	8.55	8.82	9.08	9.33	9.58	9.82	10.05	10.27	10.47	10.66
63	6.20	7.13	7.78	8.19	8.50	8.78	9.05	9.32	9.57	9.83	10.08	10.31	10.54	10.75	10.94
64	6.36	7.32	7.98	8.40	8.72	9.01	9.29	9.56	9.82	10.08	10.33	10.58	10.81	11.03	11.23
65	6.52	7.50	8.19	8.62	8.94	9.24	9.53	9.80	10.07	10.33	10.59	10.84	11.08	11.31	11.52
66	6.69	7.69	8.39	8.83	9.17	9.47	9.76	10.04	10.32	10.59	10.85	11.11	11.35	11.59	11.81
67	6.86	7.88	8.60	9.05	9.39	9.70	10.00	10.29	10.57	10.85	11.12	11.38	11.63	11.87	12.10
68	7.03	8.08	8.81	9.27	9.62	9.94	10.24	10.54	10.83	11.11	11.39	11.66	11.92	12.16	12.40
69	7.20	8.27	9.02	9.49	9.85	10.17	10.49	10.79	11.09	11.38	11.66	11.94	12.20	12.46	12.70
70	7.37	8.47	9.23	9.71	10.08	10.41	10.73	11.04	11.35	11.65	11.94	12.22	12.49	12.75	13.00
71	7.54	8.66	9.44	9.94	10.31	10.65	10.98	11.30	11.61	11.92	12.22	12.51	12.79	13.05	13.31
72	7.71	8.86	9.66	10.16	10.55	10.89	11.23	11.55	11.87	12.19	12.50	12.80	13.08	13.36	13.62
73	7.89	9.06	9.88	10.39	10.78	11.14	11.48	11.81	12.14	12.46	12.78	13.09	13.38	13.67	13.93
74	8.06	9.26	10.10	10.62	11.02	11.38	11.73	12.07	12.41	12.74	13.06	13.38	13.68	13.97	14.25
75	8.24	9.46	10.32	10.85	11.26	11.63	11.99	12.34	12.68	13.02	13.35	13.67	13.98	14.28	14.56
76	8.42	9.67	10.54	11.09	11.50	11.88	12.25	12.60	12.96	13.30	13.64	13.97	14.28	14.59	14.88
77	8.60	9.87	10.77	11.32	11.75	12.14	12.51	12.87	13.23	13.58	13.93	14.26	14.59	14.90	15.20
78	8.78	10.08	10.99	11.56	11.99	12.39	12.77	13.14	13.50	13.86	14.21	14.56	14.89	15.21	15.52
79	8.96	10.29	11.22	11.80	12.24	12.64	13.03	13.41	13.78	14.14	14.50	14.85	15.19	15.52	15.84
80	9.14	10.50	11.45	12.04	12.49	12.90	13.29	13.68	14.05	14.42	14.79	15.14	15.49	15.83	16.16
81	9.32	10.71	11.68	12.28	12.74	13.16	13.56	13.95	14.33	14.71	15.08	15.44	15.80	16.14	16.48
82	9.51	10.92	11.91	12.52	12.99	13.42	13.82	14.23	14.61	15.00	15.37	15.74	16.11	16.46	16.80
83	9.69	11.13	12.14	12.76	13.24	13.67	14.09	14.50	14.90	15.29	15.67	16.05	16.42	16.78	17.13
84	9.88	11.35	12.37	13.01	13.49	13.93	14.36	14.78	15.18	15.58	15.97	16.36	16.73	17.10	17.46
85	10.07	11.56	12.61	13.25	13.75	14.20	14.63	15.06	15.47	15.88	16.28	16.67	17.05	17.43	17.79
86	10.26	11.78	12.84	13.50	14.00	14.46	14.91	15.34	15.76	16.18	16.59	16.99	17.38	17.76	18.13
87	10.45	12.00	13.08	13.75	14.26	14.73	15.18	15.62	16.05	16.48	16.90	17.31	17.71	18.10	18.48
88	10.64	12.22	13.32	14.00	14.52	15.00	15.46	15.91	16.35	16.78	17.21	17.63	18.04	18.44	18.83
89	10.83	12.44	13.56	14.26	14.79	15.28	15.74	16.20	16.65	17.09	17.53	17.96	18.38	18.79	19.19
90	11.02	12.66	13.80	14.51	15.05	15.55	16.03	16.50	16.95	17.40	17.85	18.29	18.72	19.14	19.55
91	11.22	12.88	14.04	14.77	15.32	15.82	16.31	16.79	17.26	17.72	18.17	18.62	19.06	19.49	19.91
92	11.41	13.10	14.29	15.02	15.58	16.10	16.60	17.08	17.56	18.03	18.49	18.95	19.40	19.84	20.27
93	11.61	13.33	14.53	15.28	15.85	16.37	16.88	17.38	17.86	18.34	18.81	19.28	19.74	20.19	20.63
94	11.81	13.55	14.78	15.54	16.12	16.65	17.17	17.67	18.16	18.65	19.13	19.61	20.08	20.54	20.99
95	12.01	13.78	15.03	15.81	16.39	16.94	17.46	17.97	18.47	18.96	19.45	19.94	20.42	20.89	21.35
96	12.21	14.01	15.28	16.07	16.67	17.22	17.75	18.27	18.78	19.28	19.78	20.27	20.76	21.24	21.71
97	12.41	14.24	15.53	16.33	16.94	17.50	18.04	18.57	19.09	19.60	20.10	20.60	21.10	21.59	22.07
98	12.61	14.47	15.78	16.60	17.21	17.78	18.33	18.87	19.40	19.92	20.43	20.94	21.44	21.94	22.43
99	12.82	14.70	16.03	16.86	17.49	18.07	18.63	19.17	19.71	20.24	20.76	21.28	21.79	22.30	22.80
100	13.02	14.94	16.28	17.13	17.77	18.36	18.93	19.48	20.03	20.57	21.10	21.62	22.14	22.66	23.17
101	13.23	15.17	16.54	17.40	18.05	18.65	19.23	19.79	20.34	20.89	21.43	21.97	22.50	23.02	23.54
102	13.43	15.41	16.80	17.67	18.33	18.94	19.53	20.10	20.66	21.22	21.77	22.31	22.85	23.39	23.92
103	13.64	15.65	17.06	17.95	18.61	19.23	19.83	20.41	20.98	21.54	22.10	22.66	23.21	23.76	24.30
104	13.85	15.89	17.32	18.22	18.90	19.53	20.13	20.72	21.30	21.87	22.44	23.00	23.57	24.13	24.68
105	14.06	16.13	17.59	18.50	19.18	19.82	20.44	21.04	21.63	22.21	22.78	23.35	23.92	24.49	25.06
106	14.27	16.37	17.85	18.78	19.47	20.12	20.74	21.35	21.95	22.54	23.13	23.71	24.28	24.86	25.43
107	14.48	16.61	18.12	19.06	19.76	20.41	21.05	21.67	22.28	22.88	23.47	24.06	24.65	25.23	25.81
108	14.69	16.86	18.39	19.34	20.05	20.72	21.36	21.98	22.60	23.21	23.82	24.42	25.02	25.61	26.20
109	14.90	17.10	18.66	19.63	20.34	21.02	21.67	22.31	22.93	23.55	24.16	24.78	25.38	25.99	26.59
110	15.12	17.35	18.93	19.91	20.64	21.32	21.98	22.63	23.26	23.89	24.51	25.13	25.75	26.37	26.98
111	15.33	17.60	19.20	20.20	20.93	21.62	22.29	22.95	23.60	24.23	24.87	25.50	26.12	26.75	27.37
112	15.55	17.85	19.48	20.49	21.23	21.93	22.61	23.27	23.93	24.58	25.23	25.87	26.50	27.13	27.76
113	15.77	18.10	19.76	20.78	21.53	22.24	22.93	23.60	24.27	24.93	25.59	26.24	26.89	27.52	28.16
114	15.98	18.35	20.04	21.07	21.83	22.55	23.25	23.93	24.61	25.28	25.95	26.61	27.27	27.92	28.57
115	16.20	18.60	20.32	21.36	22.13	22.86	23.57	24.26	24.95	25.63	26.31	26.98	27.65	28.32	28.98
116	16.42	18.85	20.60	21.66	22.43	23.17	23.89	24.60	25.29	25.98	26.67	27.36	28.03	28.71	29.38
117	16.64	19.11	20.88	21.95	22.74	23.48	24.22	24.93	25.64	26.34	27.03	27.73	28.41	29.09	29.77
118	16.86	19.36	21.16	22.24	23.04	23.80	24.54	25.27	25.98	26.69	27.40	28.10	28.80	29.48	30.16
119	17.08	19.62	21.45	22.54	23.35	24.12	24.87	25.60	26.33	27.05	27.76	28.47	29.18	29.87	30.56
120	17.30	19.88	21.73	22.84	23.66	24.44	25.20	25.94	26.67	27.40	28.12	28.84	29.55	30.26	30.96

Table 20.--Log weights for scaling lengths of 34 to 60 feet: density index = 46 pounds per cubic foot

(Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet)

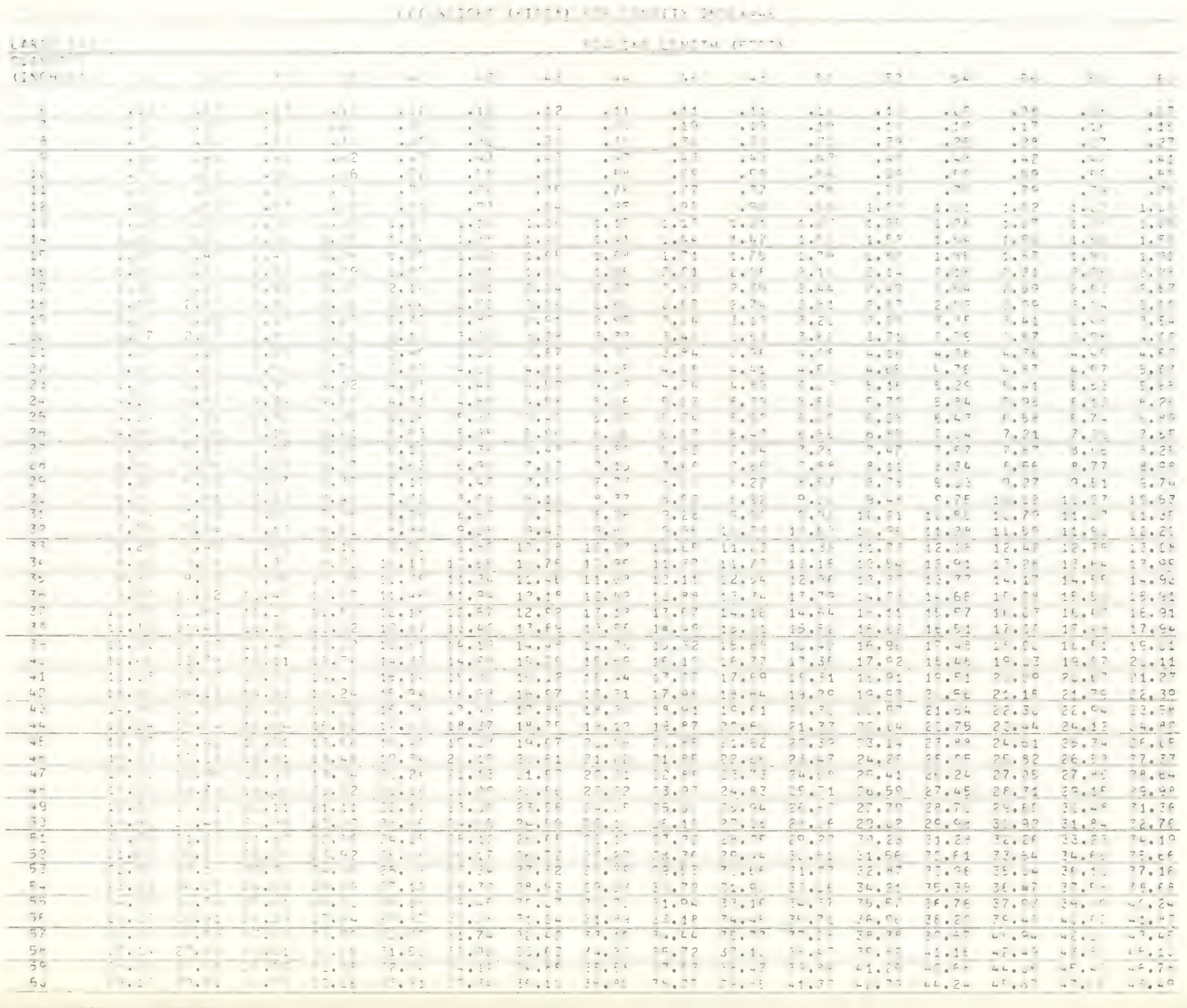


Table 21.--Log weights for scaling lengths of 4 to 32 feet: density index = 48 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KTOS*) FOR DENSITY INDEX=48

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
6	.06	.08	.09	.11	.12	.13	.14	.15	.16	.17	.18	.19	.20	.21	.22
7	.08	.11	.13	.15	.17	.19	.21	.22	.24	.25	.27	.28	.29	.31	.32
8	.11	.15	.18	.21	.24	.27	.29	.32	.34	.36	.38	.40	.42	.44	.46
9	.14	.20	.24	.28	.32	.36	.39	.43	.46	.49	.52	.55	.57	.60	.62
10	.18	.25	.31	.36	.41	.46	.50	.54	.58	.62	.66	.69	.73	.76	.79
11	.22	.31	.38	.44	.50	.56	.61	.66	.71	.76	.80	.85	.89	.93	.97
12	.27	.37	.46	.53	.60	.67	.73	.79	.85	.91	.96	1.01	1.06	1.11	1.16
13	.32	.44	.54	.63	.71	.79	.86	.93	1.00	1.07	1.13	1.19	1.25	1.31	1.36
14	.37	.51	.63	.73	.83	.92	1.00	1.08	1.16	1.24	1.31	1.38	1.45	1.51	1.58
15	.43	.59	.73	.85	.96	1.06	1.16	1.25	1.34	1.43	1.51	1.59	1.67	1.74	1.82
16	.49	.67	.83	.97	1.09	1.21	1.32	1.42	1.52	1.62	1.72	1.81	1.89	1.98	2.06
17	.55	.76	.93	1.08	1.23	1.36	1.48	1.59	1.71	1.81	1.92	2.02	2.12	2.21	2.30
18	.62	.85	1.04	1.21	1.37	1.51	1.65	1.77	1.90	2.02	2.13	2.24	2.35	2.45	2.55
19	.69	.95	1.16	1.35	1.52	1.68	1.83	1.97	2.11	2.24	2.36	2.48	2.60	2.71	2.82
20	.76	1.05	1.29	1.49	1.68	1.86	2.02	2.17	2.32	2.46	2.60	2.73	2.86	2.98	3.10
21	.84	1.15	1.41	1.64	1.84	2.03	2.21	2.38	2.54	2.69	2.84	2.98	3.12	3.25	3.38
22	.92	1.26	1.54	1.78	2.01	2.21	2.41	2.59	2.76	2.93	3.09	3.24	3.39	3.53	3.67
23	1.00	1.37	1.67	1.93	2.17	2.39	2.60	2.80	2.98	3.16	3.33	3.50	3.66	3.81	3.96
24	1.08	1.48	1.80	2.08	2.34	2.57	2.80	3.01	3.21	3.40	3.58	3.76	3.93	4.09	4.25
25	1.17	1.59	1.94	2.24	2.51	2.76	3.00	3.23	3.44	3.65	3.84	4.03	4.21	4.38	4.55
26	1.26	1.71	2.08	2.40	2.69	2.96	3.21	3.45	3.68	3.90	4.11	4.31	4.50	4.68	4.86
27	1.35	1.83	2.23	2.57	2.88	3.16	3.43	3.69	3.93	4.16	4.38	4.59	4.80	4.99	5.18
28	1.44	1.96	2.38	2.75	3.07	3.37	3.66	3.93	4.19	4.44	4.67	4.90	5.11	5.32	5.52
29	1.54	2.09	2.54	2.93	3.28	3.59	3.89	4.18	4.46	4.72	4.97	5.21	5.44	5.66	5.87
30	1.64	2.23	2.71	3.12	3.49	3.83	4.15	4.45	4.74	5.02	5.28	5.54	5.78	6.01	6.24
31	1.74	2.37	2.88	3.32	3.71	4.07	4.41	4.73	5.04	5.33	5.61	5.88	6.13	6.38	6.62
32	1.85	2.51	3.05	3.52	3.93	4.31	4.67	5.02	5.34	5.65	5.95	6.23	6.50	6.76	7.01
33	1.96	2.66	3.23	3.72	4.16	4.56	4.94	5.30	5.65	5.98	6.29	6.59	6.87	7.14	7.41
34	2.07	2.81	3.41	3.93	4.39	4.81	5.21	5.59	5.96	6.31	6.64	6.95	7.25	7.53	7.81
35	2.18	2.96	3.60	4.14	4.63	5.07	5.49	5.89	6.27	6.64	6.99	7.32	7.63	7.93	8.22
36	2.30	3.12	3.79	4.36	4.87	5.34	5.78	6.20	6.60	6.98	7.35	7.69	8.02	8.33	8.63
37	2.42	3.28	3.98	4.58	5.12	5.61	6.07	6.52	6.94	7.34	7.72	8.08	8.42	8.75	9.06
38	2.54	3.44	4.18	4.80	5.37	5.88	6.37	6.83	7.28	7.70	8.10	8.48	8.83	9.17	9.50
39	2.66	3.61	4.38	5.03	5.62	6.16	6.67	7.16	7.62	8.07	8.49	8.88	9.26	9.61	9.96
40	2.79	3.78	4.59	5.27	5.89	6.45	6.98	7.49	7.98	8.44	8.88	9.30	9.69	10.06	10.42
41	2.92	3.96	4.80	5.51	6.16	6.74	7.30	7.83	8.34	8.83	9.29	9.72	10.13	10.52	10.89
42	3.05	4.14	5.02	5.76	6.43	7.04	7.62	8.18	8.71	9.22	9.70	10.16	10.58	10.98	11.37
43	3.18	4.32	5.24	6.01	6.71	7.35	7.95	8.53	9.09	9.62	10.12	10.60	11.04	11.46	11.86
44	3.32	4.50	5.46	6.26	6.99	7.65	8.28	8.89	9.47	10.02	10.55	11.04	11.51	11.95	12.36
45	3.46	4.69	5.68	6.51	7.27	7.96	8.61	9.24	9.85	10.43	10.97	11.49	11.98	12.44	12.87
46	3.60	4.88	5.91	6.77	7.55	8.27	8.95	9.61	10.24	10.84	11.41	11.95	12.45	12.93	13.38
47	3.74	5.07	6.14	7.03	7.84	8.59	9.29	9.97	10.63	11.26	11.85	12.41	12.93	13.43	13.90
48	3.88	5.26	6.37	7.30	8.14	8.91	9.64	10.35	11.03	11.68	12.30	12.88	13.42	13.93	14.42
49	4.03	5.46	6.61	7.57	8.44	9.24	10.00	10.73	11.43	12.11	12.75	13.35	13.92	14.45	14.95
50	4.18	5.66	6.85	7.84	8.74	9.58	10.35	11.12	11.84	12.54	13.20	13.83	14.41	14.96	15.48
51	4.33	5.86	7.09	8.12	9.05	9.91	10.72	11.50	12.25	12.97	13.65	14.30	14.90	15.47	16.00
52	4.48	6.06	7.34	8.39	9.36	10.25	11.08	11.89	12.66	13.40	14.11	14.77	15.40	15.98	16.53
53	4.63	6.27	7.59	8.67	9.67	10.59	11.45	12.28	13.08	13.84	14.57	15.25	15.90	16.50	17.07
54	4.79	6.48	7.84	8.96	9.98	10.93	11.82	12.68	13.50	14.29	15.04	15.74	16.41	17.03	17.61
55	4.95	6.69	8.09	9.24	10.30	11.28	12.20	13.08	13.93	14.74	15.51	16.24	16.92	17.56	18.16
56	5.11	6.90	8.35	9.53	10.62	11.63	12.58	13.49	14.36	15.20	15.99	16.74	17.44	18.10	18.72
57	5.27	7.12	8.61	9.83	10.95	11.99	12.97	13.91	14.81	15.67	16.48	17.25	17.97	18.65	19.29
58	5.43	7.34	8.88	10.13	11.28	12.36	13.37	14.34	15.26	16.15	16.98	17.77	18.51	19.21	19.87
59	5.60	7.56	9.14	10.43	11.62	12.72	13.77	14.77	15.72	16.63	17.49	18.30	19.06	19.78	20.46
60	5.77	7.79	9.42	10.74	11.96	13.10	14.17	15.20	16.18	17.12	18.00	18.84	19.62	20.36	21.06

* KTOS=Kiln Tested

Table 22.--Log weights for scaling lengths of 34 to 60 feet: density index = 48 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG SCALING DIAMETER (INCHES)	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
6	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11
7	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13	.13
8	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
9	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17
10	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19
11	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21
12	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23
13	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25
14	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27
15	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29	.29
16	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31
17	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
18	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35
19	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37
20	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39
21	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41	.41
22	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43	.43
23	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45
24	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47
25	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49
26	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51
27	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53
28	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55
29	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57	.57
30	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59
31	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61
32	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63
33	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65
34	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67
35	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69
36	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71
37	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73
38	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
39	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77
40	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79
41	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81	.81
42	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83
43	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85
44	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87
45	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89
46	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91
47	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93	.93
48	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
49	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97
50	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99
51	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
52	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
53	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
54	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
55	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09
56	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
57	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
58	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
59	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
60	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19

* 1<IF=1...

Table 23.--Log weights for scaling lengths of 4 to 32 feet: density index = 50 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

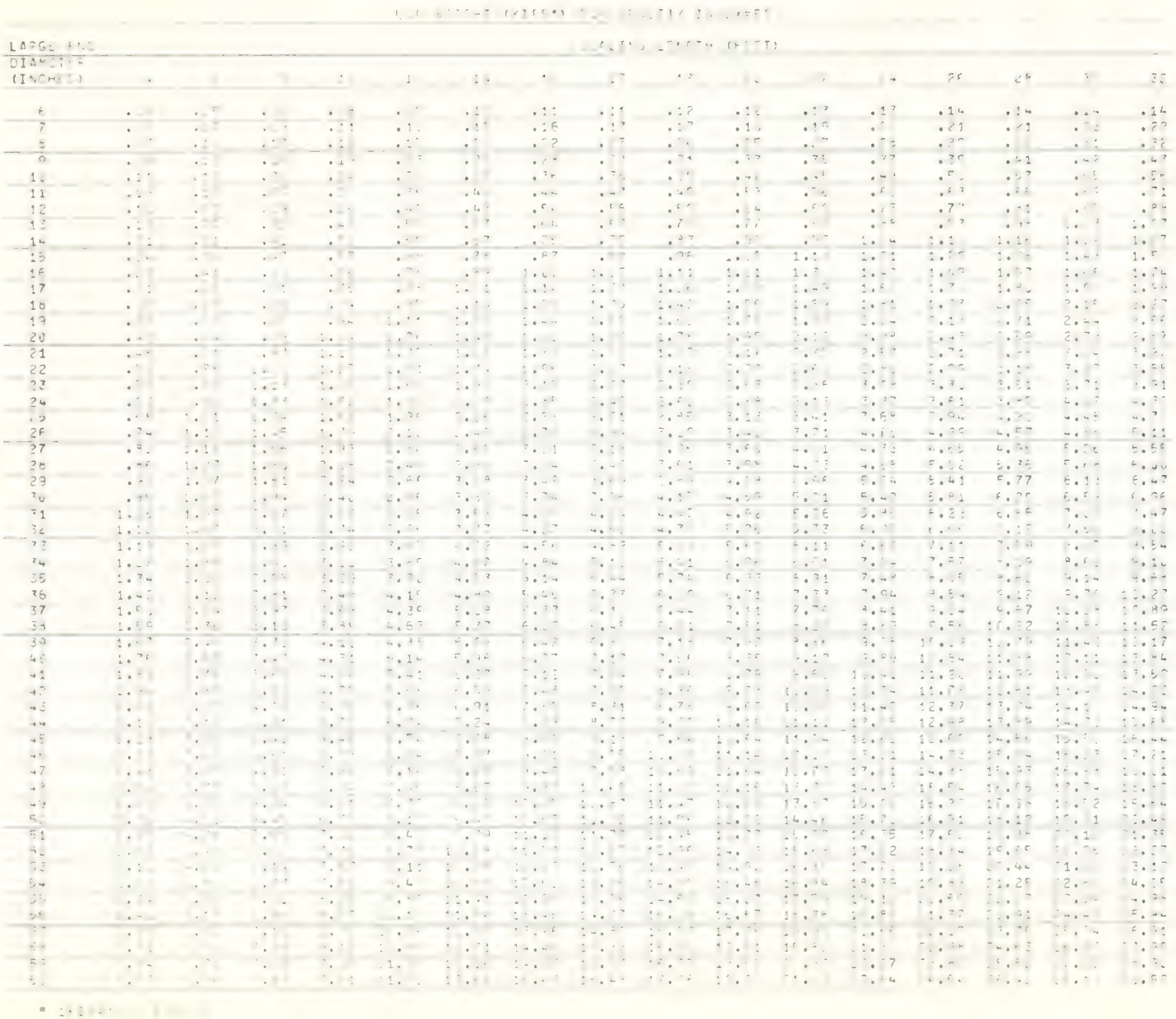
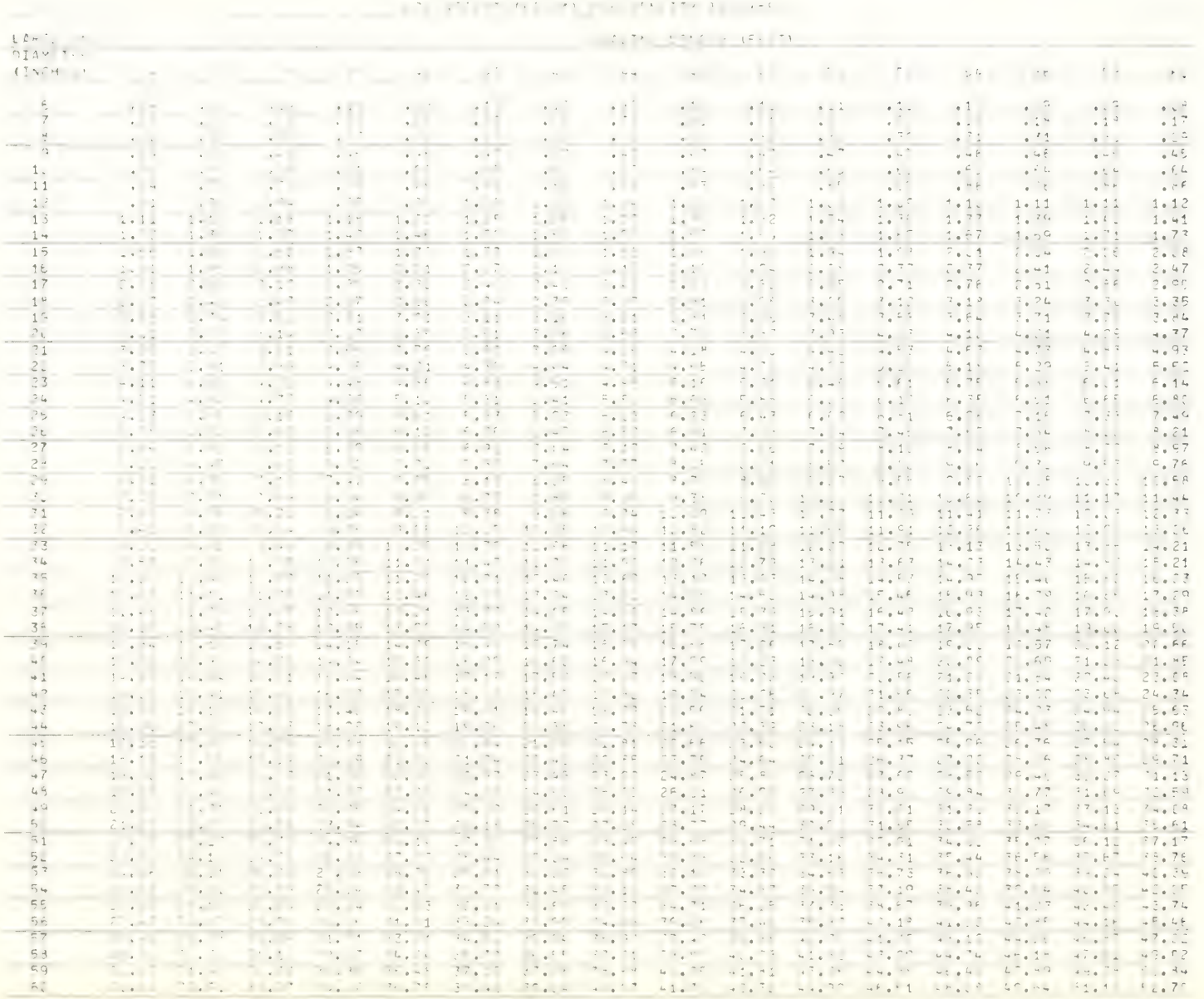


Table 24.--Log weights for scaling lengths of 34 to 60 feet: density index = 50 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]



* 1 KIP = 1,000 POUNDS

Table 25.--Log weights for scaling lengths of 4 to 32 feet: density index = 52 pounds per cubic foot

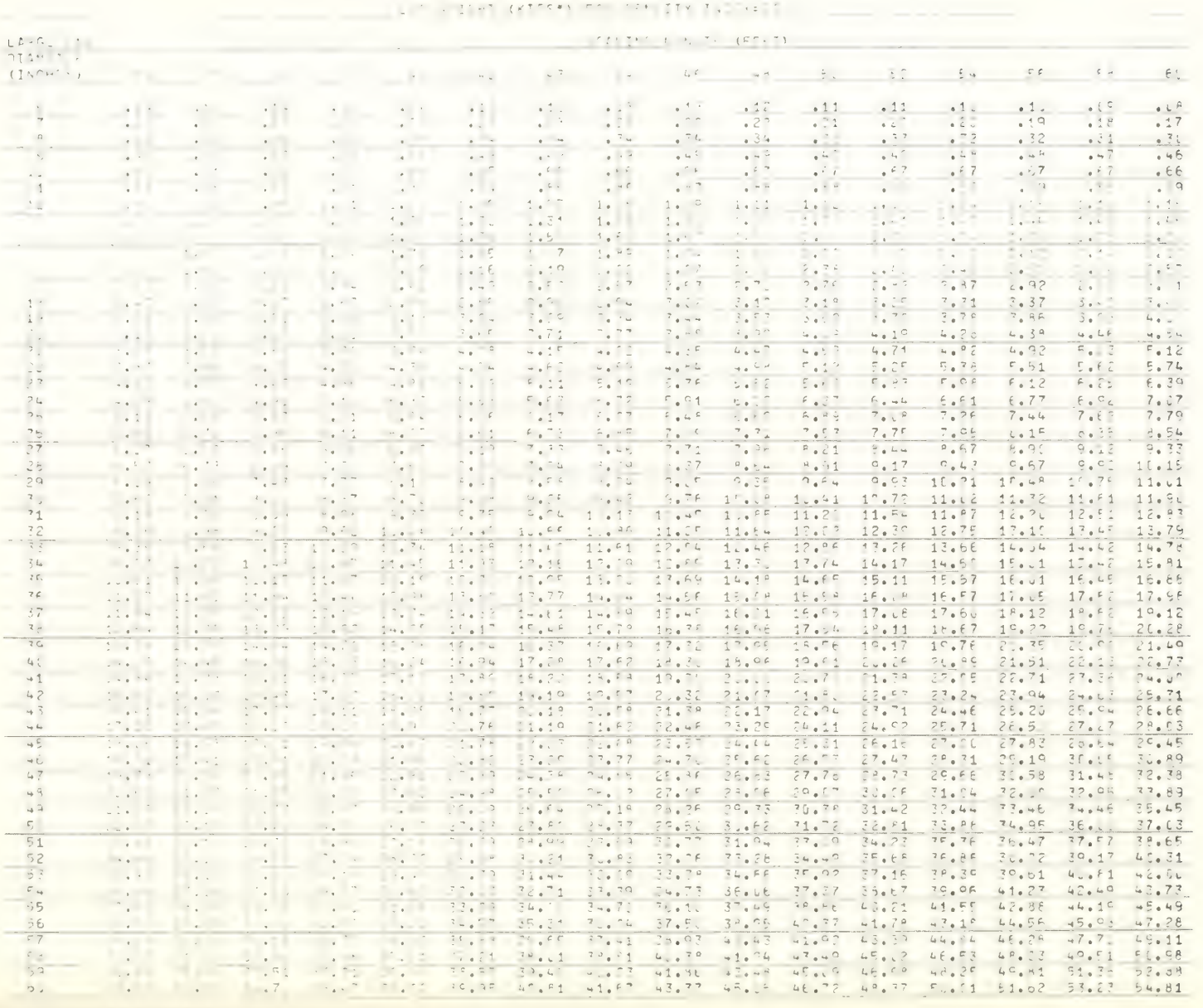
[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (WEIGHT) FOR DENSITY INDEX=52

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	
6	.04	.07	.09	.12	.11	.11	.11	.12	.14	.13	.13	.14	.14	.14	.15	.15
7	.06	.09	.11	.13	.14	.15	.17	.17	.18	.19	.20	.21	.21	.22	.22	.23
8	.07	.11	.14	.16	.18	.21	.23	.24	.25	.26	.27	.28	.29	.31	.31	.32
9	.09	.13	.17	.21	.24	.27	.29	.31	.33	.35	.37	.38	.41	.42	.44	.45
10	.11	.16	.21	.26	.30	.34	.37	.39	.41	.43	.45	.47	.50	.52	.55	.57
11	.13	.19	.25	.31	.36	.41	.45	.48	.51	.53	.55	.57	.60	.63	.66	.68
12	.15	.22	.29	.37	.43	.49	.54	.58	.61	.64	.67	.69	.72	.76	.79	.82
13	.18	.26	.34	.43	.50	.57	.63	.68	.72	.75	.78	.81	.84	.87	.91	.94
14	.21	.30	.39	.49	.58	.66	.73	.78	.83	.87	.90	.94	.97	1.01	1.04	1.07
15	.24	.34	.45	.56	.66	.75	.83	.89	.95	1.00	1.03	1.07	1.11	1.15	1.18	1.21
16	.27	.39	.51	.63	.74	.84	.93	1.00	1.07	1.12	1.16	1.20	1.24	1.28	1.32	1.35
17	.30	.43	.57	.70	.83	.94	1.04	1.12	1.19	1.25	1.30	1.34	1.38	1.42	1.46	1.50
18	.33	.48	.63	.78	.92	1.04	1.15	1.24	1.32	1.38	1.44	1.49	1.53	1.57	1.61	1.65
19	.37	.53	.70	.86	1.01	1.15	1.27	1.37	1.45	1.52	1.58	1.63	1.68	1.72	1.77	1.81
20	.40	.58	.76	.94	1.11	1.26	1.39	1.49	1.58	1.66	1.72	1.78	1.83	1.88	1.92	1.97
21	.44	.63	.83	1.02	1.20	1.36	1.50	1.62	1.72	1.80	1.87	1.93	1.98	2.03	2.08	2.13
22	.48	.68	.89	1.10	1.29	1.47	1.62	1.74	1.85	1.94	2.01	2.08	2.13	2.19	2.24	2.29
23	.51	.73	.96	1.18	1.39	1.57	1.73	1.87	1.98	2.08	2.16	2.23	2.29	2.35	2.40	2.45
24	.55	.78	1.03	1.26	1.48	1.68	1.85	1.99	2.12	2.22	2.31	2.38	2.45	2.51	2.56	2.62
25	.59	.84	1.09	1.34	1.58	1.78	1.96	2.12	2.25	2.36	2.45	2.53	2.60	2.66	2.72	2.78
26	.63	.89	1.16	1.42	1.67	1.89	2.08	2.24	2.38	2.50	2.59	2.68	2.75	2.82	2.88	2.94
27	.67	.94	1.22	1.50	1.76	1.99	2.19	2.36	2.51	2.63	2.73	2.82	2.90	2.97	3.04	3.10
28	.71	1.00	1.29	1.58	1.85	2.09	2.30	2.48	2.63	2.76	2.87	2.96	3.04	3.12	3.19	3.26
29	.75	1.06	1.36	1.66	1.94	2.20	2.42	2.60	2.76	2.90	3.01	3.11	3.19	3.27	3.35	3.42
30	.79	1.11	1.43	1.75	2.04	2.30	2.53	2.73	2.89	3.03	3.15	3.25	3.34	3.43	3.50	3.58
31	.83	1.17	1.50	1.83	2.14	2.41	2.65	2.85	3.02	3.17	3.29	3.40	3.49	3.58	3.66	3.74
32	.87	1.23	1.57	1.92	2.24	2.52	2.77	2.98	3.16	3.31	3.44	3.55	3.65	3.74	3.82	3.90
33	.91	1.28	1.64	2.00	2.34	2.64	2.89	3.11	3.30	3.46	3.59	3.71	3.81	3.90	3.99	4.07
34	.95	1.34	1.71	2.09	2.44	2.75	3.02	3.25	3.44	3.61	3.75	3.87	3.97	4.07	4.16	4.24
35	.99	1.39	1.78	2.17	2.54	2.87	3.14	3.38	3.59	3.76	3.90	4.03	4.14	4.24	4.33	4.42
36	1.03	1.45	1.85	2.26	2.64	2.98	3.27	3.52	3.73	3.91	4.06	4.19	4.30	4.41	4.50	4.59
37	1.06	1.50	1.92	2.34	2.74	3.09	3.39	3.65	3.87	4.06	4.21	4.35	4.47	4.57	4.67	4.76
38	1.10	1.56	1.99	2.43	2.84	3.21	3.52	3.78	4.01	4.20	4.37	4.51	4.63	4.74	4.84	4.93
39	1.14	1.61	2.06	2.51	2.94	3.32	3.64	3.92	4.15	4.35	4.52	4.67	4.80	4.91	5.01	5.11
40	1.18	1.67	2.13	2.60	3.04	3.43	3.77	4.05	4.30	4.50	4.68	4.83	4.96	5.08	5.19	5.28
41	1.22	1.72	2.20	2.68	3.14	3.54	3.89	4.19	4.44	4.65	4.83	4.99	5.13	5.25	5.36	5.46
42	1.26	1.78	2.27	2.77	3.24	3.66	4.02	4.32	4.58	4.80	4.99	5.15	5.29	5.42	5.53	5.64
43	1.30	1.84	2.34	2.86	3.34	3.77	4.14	4.46	4.72	4.95	5.14	5.31	5.46	5.59	5.70	5.81
44	1.34	1.89	2.41	2.94	3.44	3.88	4.27	4.59	4.87	5.10	5.30	5.47	5.62	5.75	5.87	5.98
45	1.38	1.95	2.48	3.03	3.54	4.00	4.39	4.73	5.01	5.25	5.45	5.63	5.78	5.92	6.04	6.15
46	1.42	2.01	2.55	3.11	3.64	4.11	4.52	4.86	5.16	5.40	5.61	5.79	5.95	6.09	6.21	6.33
47	1.46	2.06	2.62	3.20	3.74	4.23	4.64	5.00	5.30	5.55	5.76	5.95	6.11	6.26	6.39	6.50
48	1.50	2.12	2.69	3.28	3.84	4.34	4.77	5.13	5.44	5.70	5.92	6.11	6.28	6.43	6.56	6.68
49	1.54	2.17	2.76	3.37	3.94	4.45	4.89	5.27	5.59	5.85	6.08	6.27	6.44	6.60	6.73	6.86
50	1.58	2.23	2.83	3.45	4.04	4.57	5.02	5.40	5.73	6.00	6.23	6.43	6.61	6.76	6.90	7.03
51	1.62	2.28	2.90	3.54	4.14	4.68	5.14	5.54	5.87	6.15	6.39	6.59	6.77	6.93	7.07	7.20
52	1.66	2.34	2.97	3.62	4.24	4.79	5.27	5.67	6.02	6.30	6.54	6.75	6.93	7.09	7.24	7.37
53	1.70	2.40	3.04	3.71	4.34	4.91	5.39	5.81	6.16	6.45	6.70	6.91	7.09	7.26	7.41	7.54
54	1.74	2.45	3.11	3.79	4.44	5.02	5.52	5.94	6.30	6.60	6.85	7.07	7.26	7.42	7.58	7.72
55	1.78	2.51	3.18	3.88	4.54	5.13	5.64	6.07	6.44	6.75	7.00	7.23	7.42	7.59	7.75	7.89
56	1.82	2.57	3.25	3.96	4.64	5.24	5.76	6.20	6.58	6.89	7.16	7.39	7.58	7.76	7.92	8.06
57	1.86	2.62	3.32	4.05	4.74	5.36	5.89	6.34	6.72	7.04	7.31	7.54	7.74	7.92	8.08	8.23
58	1.90	2.68	3.39	4.13	4.84	5.47	6.01	6.47	6.86	7.19	7.46	7.70	7.90	8.08	8.25	8.40
59	1.94	2.73	3.46	4.22	4.94	5.58	6.14	6.61	7.01	7.34	7.62	7.86	8.07	8.25	8.41	8.57
60	1.98	2.79	3.53	4.30	5.04	5.70	6.26	6.74	7.15	7.49	7.78	8.02	8.23	8.41	8.58	8.74

Table 26.--Log weights for scaling lengths of 34 to 60 feet: density index = 52 pounds per cubic foot

[Assumed taper of ' inch per 8 feet, trim allowance of 1 inch per 4 feet]



* 1KIP=1.

Table 27.--Log weights for scaling lengths of 4 to 32 feet: density index = 54 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

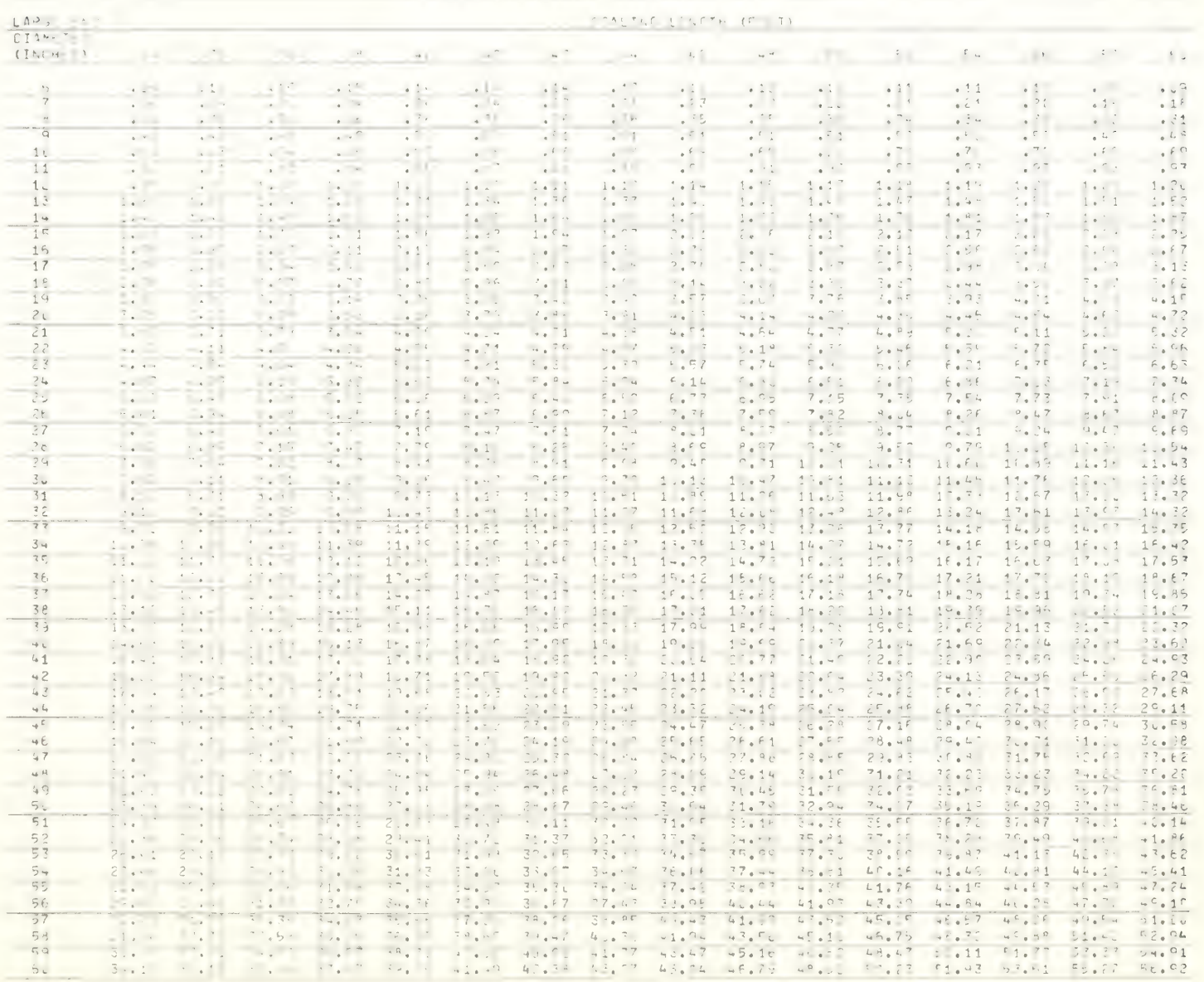
LOG WEIGHT (KIPS*) FOR DENSITY INDEX=54

LARGE-END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
6	.06	.08	.09	.10	.11	.11	.12	.12	.13	.13	.14	.14	.15	.15	.15
7	.09	.12	.14	.15	.16	.17	.18	.19	.20	.21	.22	.23	.24	.25	.24
8	.12	.16	.19	.21	.22	.23	.24	.25	.26	.27	.29	.30	.31	.33	.34
9	.15	.20	.24	.27	.29	.31	.32	.33	.35	.36	.38	.40	.42	.44	.45	.47
10	.19	.25	.30	.34	.36	.38	.40	.42	.44	.46	.48	.51	.54	.57	.59	.61
11	.23	.30	.36	.41	.44	.46	.48	.50	.53	.55	.58	.61	.64	.68	.71	.74	.77
12	.27	.36	.43	.48	.52	.55	.57	.60	.63	.66	.69	.73	.77	.81	.84	.88	.91	.95
13	.32	.42	.50	.56	.60	.64	.67	.70	.73	.76	.80	.84	.89	.94	.98	1.03	1.07	1.11
14	.37	.48	.57	.64	.69	.73	.76	.80	.84	.87	.91	.96	1.01	1.07	1.12	1.17	1.21	1.26	1.30
15	.42	.55	.65	.73	.78	.83	.86	.90	.94	.98	1.03	1.08	1.14	1.20	1.26	1.31	1.36	1.41	1.45	1.50
16	.47	.62	.73	.82	.88	.93	.97	1.01	1.05	1.10	1.15	1.21	1.27	1.34	1.40	1.46	1.51	1.57	1.62	1.67
17	.53	.69	.82	.91	.98	1.04	1.08	1.12	1.17	1.22	1.28	1.34	1.41	1.48	1.55	1.62	1.68	1.74	1.79	1.85
18	.59	.77	.91	1.01	1.09	1.15	1.20	1.25	1.30	1.35	1.41	1.48	1.56	1.64	1.72	1.79	1.86	1.92	1.98	2.05
19	.65	.85	1.00	1.11	1.20	1.27	1.32	1.37	1.43	1.49	1.55	1.63	1.71	1.80	1.88	1.96	2.03	2.10	2.17	2.23
20	.71	.93	1.09	1.21	1.31	1.38	1.44	1.50	1.56	1.62	1.69	1.77	1.86	1.95	2.04	2.13	2.21	2.28	2.35	2.42
21	.78	1.02	1.19	1.32	1.42	1.50	1.57	1.63	1.69	1.76	1.83	1.92	2.01	2.11	2.21	2.30	2.39	2.46	2.54	2.61
22	.85	1.11	1.29	1.43	1.54	1.63	1.70	1.77	1.83	1.90	1.98	2.07	2.17	2.28	2.38	2.48	2.57	2.65	2.73	2.81
23	.92	1.20	1.40	1.55	1.67	1.76	1.84	1.91	1.98	2.05	2.13	2.23	2.34	2.45	2.56	2.67	2.76	2.85	2.93	3.02
24	1.00	1.30	1.51	1.67	1.80	1.90	1.98	2.06	2.13	2.21	2.29	2.40	2.51	2.63	2.75	2.86	2.96	3.06	3.15	3.24
25	1.08	1.40	1.63	1.80	1.93	2.04	2.13	2.21	2.29	2.37	2.46	2.57	2.69	2.82	2.94	3.06	3.17	3.27	3.37	3.47
26	1.16	1.50	1.74	1.93	2.07	2.19	2.28	2.37	2.45	2.54	2.63	2.75	2.88	3.01	3.14	3.27	3.38	3.49	3.60	3.70
27	1.24	1.60	1.86	2.06	2.21	2.33	2.43	2.53	2.61	2.70	2.80	2.93	3.07	3.21	3.35	3.48	3.60	3.71	3.83	3.94
28	1.32	1.71	1.98	2.19	2.35	2.48	2.59	2.69	2.78	2.87	2.98	3.11	3.26	3.41	3.56	3.70	3.83	3.95	4.07	4.18
29	1.41	1.81	2.10	2.32	2.50	2.63	2.75	2.85	2.95	3.05	3.16	3.30	3.46	3.62	3.77	3.92	4.06	4.19	4.31	4.43
30	1.50	1.92	2.22	2.46	2.64	2.79	2.91	3.02	3.12	3.23	3.34	3.49	3.66	3.82	3.98	4.14	4.29	4.43	4.56	4.68
31	1.59	2.03	2.35	2.60	2.79	2.95	3.08	3.19	3.30	3.41	3.53	3.69	3.86	4.03	4.20	4.37	4.53	4.67	4.81	4.94
32	1.68	2.14	2.48	2.74	2.95	3.11	3.25	3.36	3.48	3.60	3.72	3.89	4.07	4.25	4.43	4.60	4.77	4.92	5.07	5.21
33	1.77	2.25	2.61	2.89	3.11	3.28	3.42	3.54	3.66	3.79	3.92	4.09	4.28	4.47	4.66	4.84	5.01	5.17	5.33	5.48
34	1.87	2.37	2.74	3.03	3.27	3.45	3.60	3.72	3.85	3.98	4.12	4.30	4.49	4.69	4.89	5.08	5.26	5.43	5.59	5.75
35	1.96	2.48	2.87	3.18	3.42	3.62	3.77	3.90	4.03	4.17	4.32	4.51	4.71	4.92	5.12	5.32	5.51	5.69	5.86	6.02
36	2.06	2.60	3.01	3.33	3.58	3.79	3.95	4.08	4.22	4.36	4.52	4.72	4.93	5.15	5.36	5.57	5.77	5.95	6.13	6.30
37	2.16	2.72	3.15	3.48	3.75	3.96	4.13	4.27	4.41	4.56	4.73	4.93	5.15	5.38	5.61	5.82	6.03	6.22	6.41	6.59
38	2.26	2.84	3.29	3.64	3.91	4.14	4.31	4.46	4.61	4.76	4.93	5.15	5.38	5.62	5.86	6.08	6.30	6.50	6.69	6.88
39	2.36	2.96	3.43	3.79	4.08	4.31	4.49	4.65	4.80	4.96	5.14	5.37	5.61	5.86	6.11	6.34	6.57	6.78	6.98	7.17
40	2.46	3.08	3.57	3.95	4.24	4.48	4.67	4.83	4.99	5.16	5.34	5.58	5.84	6.10	6.36	6.60	6.84	7.06	7.27	7.47
41	2.57	3.21	3.71	4.10	4.41	4.65	4.85	5.02	5.18	5.36	5.55	5.80	6.06	6.33	6.60	6.85	7.09	7.32	7.54	7.75
42	2.67	3.33	3.85	4.26	4.57	4.82	5.03	5.21	5.38	5.56	5.75	6.01	6.28	6.56	6.84	7.10	7.35	7.59	7.82	8.04
43	2.78	3.46	4.00	4.41	4.74	5.00	5.21	5.40	5.57	5.76	5.96	6.23	6.51	6.80	7.09	7.36	7.62	7.87	8.10	8.33
44	2.89	3.59	4.14	4.57	4.91	5.18	5.40	5.59	5.77	5.97	6.18	6.45	6.74	7.04	7.35	7.62	7.89	8.14	8.39	8.62
45	2.99	3.72	4.29	4.73	5.08	5.36	5.59	5.78	5.97	6.17	6.39	6.67	6.97	7.28	7.60	7.88	8.15	8.41	8.67	8.91
46	3.10	3.85	4.43	4.89	5.25	5.54	5.78	5.98	6.17	6.38	6.60	6.89	7.20	7.52	7.85	8.14	8.42	8.68	8.94	9.20
47	3.21	3.98	4.58	5.05	5.42	5.72	5.97	6.18	6.38	6.59	6.82	7.12	7.43	7.76	8.10	8.40	8.69	8.96	9.23	9.49
48	3.32	4.11	4.73	5.21	5.59	5.90	6.16	6.37	6.58	6.80	7.04	7.34	7.66	8.00	8.35	8.66	8.96	9.24	9.51	9.78
49	3.43	4.24	4.88	5.38	5.77	6.08	6.34	6.57	6.78	7.00	7.25	7.56	7.89	8.24	8.59	8.91	9.22	9.51	9.79	10.06
50	3.54	4.37	5.03	5.54	5.94	6.26	6.53	6.76	6.98	7.21	7.46	7.78	8.12	8.48	8.84	9.17	9.49	9.79	10.07	10.35
51	3.65	4.50	5.18	5.71	6.12	6.45	6.72	6.96	7.18	7.42	7.68	8.01	8.36	8.73	9.10	9.44	9.77	10.08	10.37	10.65
52	3.76	4.64	5.33	5.88	6.30	6.64	6.92	7.16	7.39	7.63	7.90	8.24	8.60	8.98	9.36	9.72	10.06	10.37	10.67	10.96
53	3.87	4.77	5.49	6.05	6.48	6.83	7.12	7.37	7.60	7.85	8.12	8.48	8.85	9.24	9.63	9.99	10.34	10.67	10.98	11.27
54	3.98	4.91	5.64	6.22	6.67	7.03	7.32	7.58	7.82	8.07	8.35	8.72	9.10	9.51	9.90	10.27	10.63	10.97	11.29	11.59
55	4.09	5.04	5.80	6.39	6.85	7.22	7.52	7.79	8.03	8.29	8.58	8.96	9.35	9.77	10.17	10.55	10.92	11.27	11.60	11.91
56	4.20	5.18	5.95	6.56	7.04	7.42	7.73	8.00	8.25	8.51	8.81	9.20	9.61	10.03	10.44	10.84	11.21	11.57	11.91	12.23
57	4.31	5.31	6.11	6.73	7.22	7.61	7.93	8.20	8.46	8.73	9.03	9.44	9.86	10.29	10.71	11.12	11.50	11.87	12.22	12.55
58	4.42	5.45	6.26	6.90	7.40	7.80	8.13	8.41	8.67	8.95	9.26	9.68	10.11	10.55	10.98	11.40	11.79	12.17	12.53	12.87
59	4.53	5.58	6.41	7.07	7.58	7.99	8.33	8.62	8.88	9.16	9.49	9.92	10.36	10.81	11.25	11.68	12.08	12.47	12.84	13.19
60	4.64	5.72	6.57	7.24	7.76	8.18	8.53	8.82	9.09	9.38	9.71	10.16	10.61	11.07	11.52	11.96	12.37	12.76	13.14	13.50

* THOUSANDS OF POUNDS

Table 28.--Log weights for scaling lengths of 34 to 60 feet: density index - 54 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]



* 1KIP=1,000 POUNDS

Table 29.--Log weights for scaling lengths of 4 to 32 feet: density index = 56 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KIPS*) FOR DENSITY INDEX=56

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
6	.14	.19	.24	.29	.34	.39	.44	.49	.54	.59	.64	.69	.74	.79	.84
7	.19	.26	.33	.40	.47	.54	.61	.68	.75	.82	.89	.96	1.03	1.10	1.17
8	.25	.34	.43	.52	.61	.70	.79	.88	.97	1.06	1.15	1.24	1.33	1.42	1.51
9	.32	.43	.54	.65	.76	.87	.98	1.09	1.20	1.31	1.42	1.53	1.64	1.75	1.86
10	.39	.52	.65	.78	.91	1.04	1.17	1.30	1.43	1.56	1.69	1.82	1.95	2.08	2.21
11	.46	.61	.76	.91	1.06	1.21	1.36	1.51	1.66	1.81	1.96	2.11	2.26	2.41	2.56
12	.53	.71	.89	1.07	1.25	1.43	1.61	1.79	1.97	2.15	2.33	2.51	2.69	2.87	3.05
13	.61	.82	1.03	1.24	1.45	1.66	1.87	2.08	2.29	2.50	2.71	2.92	3.13	3.34	3.55
14	.70	.93	1.16	1.39	1.62	1.85	2.08	2.31	2.54	2.77	3.00	3.23	3.46	3.69	3.92
15	.78	1.04	1.30	1.56	1.82	2.08	2.34	2.60	2.86	3.12	3.38	3.64	3.90	4.16	4.42
16	.87	1.16	1.45	1.74	2.03	2.32	2.61	2.90	3.19	3.48	3.77	4.06	4.35	4.64	4.93
17	.96	1.28	1.60	1.92	2.24	2.56	2.88	3.20	3.52	3.84	4.16	4.48	4.80	5.12	5.44
18	1.06	1.41	1.76	2.11	2.46	2.81	3.16	3.51	3.86	4.21	4.56	4.91	5.26	5.61	5.96
19	1.16	1.54	1.92	2.30	2.68	3.06	3.44	3.82	4.20	4.58	4.96	5.34	5.72	6.10	6.48
20	1.26	1.68	2.10	2.52	2.94	3.36	3.78	4.20	4.62	5.04	5.46	5.88	6.30	6.72	7.14
21	1.37	1.83	2.29	2.75	3.21	3.67	4.13	4.59	5.05	5.51	5.97	6.43	6.89	7.35	7.81
22	1.49	1.98	2.48	2.98	3.48	3.98	4.48	4.98	5.48	5.98	6.48	6.98	7.48	7.98	8.48
23	1.61	2.14	2.68	3.22	3.76	4.30	4.84	5.38	5.92	6.46	7.00	7.54	8.08	8.62	9.16
24	1.73	2.31	2.89	3.47	4.05	4.63	5.21	5.79	6.37	6.95	7.53	8.11	8.69	9.27	9.85
25	1.86	2.48	3.10	3.72	4.34	4.96	5.58	6.20	6.82	7.44	8.06	8.68	9.30	9.92	10.54
26	1.99	2.66	3.32	3.98	4.64	5.30	5.96	6.62	7.28	7.94	8.60	9.26	9.92	10.58	11.24
27	2.13	2.84	3.55	4.26	4.97	5.68	6.39	7.10	7.81	8.52	9.23	9.94	10.65	11.36	12.07
28	2.27	3.03	3.79	4.55	5.31	6.07	6.83	7.59	8.35	9.11	9.87	10.63	11.39	12.15	12.91
29	2.42	3.23	4.04	4.85	5.66	6.47	7.28	8.09	8.90	9.71	10.52	11.33	12.14	12.95	13.76
30	2.57	3.43	4.29	5.15	6.01	6.87	7.73	8.59	9.45	10.31	11.17	12.03	12.89	13.75	14.61
31	2.73	3.64	4.55	5.46	6.37	7.28	8.19	9.10	10.01	10.92	11.83	12.74	13.65	14.56	15.47
32	2.89	3.86	4.82	5.78	6.74	7.70	8.66	9.62	10.58	11.54	12.50	13.46	14.42	15.38	16.34
33	3.06	4.08	5.10	6.12	7.14	8.16	9.18	10.20	11.22	12.24	13.26	14.28	15.30	16.32	17.34
34	3.23	4.31	5.39	6.47	7.55	8.63	9.71	10.79	11.87	12.95	14.03	15.11	16.19	17.27	18.35
35	3.41	4.55	5.69	6.83	7.97	9.11	10.25	11.39	12.53	13.67	14.81	15.95	17.09	18.23	19.37
36	3.59	4.79	5.99	7.19	8.39	9.59	10.79	11.99	13.19	14.39	15.59	16.79	17.99	19.19	20.39
37	3.78	5.04	6.30	7.56	8.82	10.08	11.34	12.60	13.86	15.12	16.38	17.64	18.90	20.16	21.42
38	3.97	5.29	6.61	7.93	9.25	10.57	11.89	13.21	14.53	15.85	17.17	18.49	19.81	21.13	22.45
39	4.17	5.55	6.93	8.31	9.69	11.07	12.45	13.83	15.21	16.59	17.97	19.35	20.73	22.11	23.49
40	4.37	5.81	7.26	8.70	10.14	11.58	13.02	14.46	15.90	17.34	18.78	20.22	21.66	23.10	24.54
41	4.57	6.08	7.59	9.10	10.61	12.12	13.63	15.14	16.65	18.16	19.67	21.18	22.69	24.20	25.71
42	4.77	6.35	7.93	9.51	11.09	12.67	14.25	15.83	17.41	18.99	20.57	22.15	23.73	25.31	26.89
43	4.98	6.63	8.28	9.93	11.58	13.23	14.88	16.53	18.18	19.83	21.48	23.13	24.78	26.43	28.08
44	5.20	6.91	8.63	10.35	12.07	13.79	15.51	17.23	18.95	20.67	22.39	24.11	25.83	27.55	29.27
45	5.41	7.20	8.99	10.78	12.57	14.36	16.15	17.94	19.73	21.52	23.31	25.10	26.89	28.68	30.47
46	5.63	7.49	9.35	11.21	13.07	14.93	16.79	18.65	20.51	22.37	24.23	26.09	27.95	29.81	31.67
47	5.85	7.78	9.72	11.65	13.58	15.51	17.44	19.37	21.30	23.23	25.16	27.09	29.02	30.95	32.88
48	6.08	8.08	10.09	12.10	14.11	16.12	18.13	20.14	22.15	24.16	26.17	28.18	30.19	32.20	34.21
49	6.31	8.39	10.47	12.55	14.63	16.71	18.79	20.87	22.95	25.03	27.11	29.19	31.27	33.35	35.43
50	6.54	8.70	10.85	13.00	15.15	17.30	19.45	21.60	23.75	25.90	28.05	30.20	32.35	34.50	36.65
51	6.78	9.01	11.24	13.46	15.68	17.90	20.12	22.34	24.56	26.78	29.00	31.22	33.44	35.66	37.88
52	7.02	9.33	11.64	13.94	16.24	18.54	20.84	23.14	25.44	27.74	30.04	32.34	34.64	36.94	39.24
53	7.26	9.65	12.04	14.42	16.80	19.18	21.56	23.94	26.32	28.70	31.08	33.46	35.84	38.22	40.60
54	7.51	9.98	12.45	14.91	17.37	19.83	22.29	24.75	27.21	29.67	32.13	34.59	37.05	39.51	41.97
55	7.76	10.31	12.86	15.41	17.96	20.51	23.06	25.61	28.16	30.71	33.26	35.81	38.36	40.91	43.46
56	8.01	10.65	13.29	15.92	18.55	21.18	23.81	26.44	29.07	31.70	34.33	36.96	39.59	42.22	44.85
57	8.27	10.99	13.71	16.43	19.15	21.87	24.59	27.31	30.03	32.75	35.47	38.19	40.91	43.63	46.35
58	8.53	11.34	14.15	16.96	19.77	22.58	25.39	28.20	31.01	33.82	36.63	39.44	42.25	45.06	47.87
59	8.80	11.69	14.59	17.49	20.39	23.29	26.19	29.09	31.99	34.89	37.79	40.69	43.59	46.49	49.39
60	9.07	12.05	15.04	18.03	21.02	24.01	27.00	29.99	32.98	35.97	38.96	41.95	44.94	47.93	50.92

Table 30.--Log weights for scaling lengths of 34 to 60 feet: density index = 56 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LARGE-END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64
6	.12	.13	.13	.14	.14	.14	.14	.15	.15	.15	.16	.16	.16	.16	.17	.17
7	.17	.18	.18	.19	.19	.19	.20	.20	.20	.21	.21	.21	.22	.22	.22	.23
8	.23	.24	.24	.25	.25	.25	.26	.26	.27	.27	.27	.28	.28	.28	.29	.29
9	.30	.31	.31	.32	.32	.33	.33	.34	.34	.35	.35	.35	.36	.36	.37	.37
10	.38	.39	.39	.40	.40	.41	.41	.42	.43	.43	.44	.44	.45	.45	.46	.46
11	.47	.48	.48	.49	.50	.50	.51	.52	.52	.53	.54	.54	.55	.56	.56	.57
12	.57	.58	.59	.60	.61	.61	.62	.63	.64	.65	.65	.66	.67	.68	.69	.69
13	.69	.70	.71	.72	.73	.74	.75	.76	.77	.78	.79	.80	.81	.82	.83	.84
14	.82	.83	.84	.85	.86	.87	.88	.89	.91	.92	.93	.94	.95	.97	.98	.99
15	.96	.98	.99	1.00	1.02	1.03	1.04	1.06	1.07	1.08	1.10	1.11	1.13	1.14	1.15	1.17
16	1.12	1.13	1.15	1.16	1.18	1.19	1.21	1.22	1.24	1.25	1.27	1.28	1.30	1.31	1.33	1.34
17	1.30	1.31	1.33	1.34	1.36	1.38	1.39	1.41	1.43	1.44	1.46	1.48	1.49	1.51	1.53	1.54
18	1.49	1.51	1.52	1.54	1.56	1.58	1.59	1.61	1.63	1.65	1.67	1.68	1.70	1.72	1.74	1.76
19	1.70	1.72	1.73	1.75	1.77	1.79	1.81	1.83	1.85	1.87	1.89	1.91	1.93	1.95	1.97	1.99
20	1.93	1.95	1.97	1.99	2.01	2.03	2.05	2.07	2.09	2.11	2.13	2.15	2.17	2.19	2.21	2.23
21	2.18	2.20	2.22	2.24	2.26	2.28	2.30	2.32	2.34	2.37	2.39	2.41	2.43	2.45	2.47	2.50
22	2.45	2.47	2.49	2.51	2.54	2.56	2.58	2.60	2.63	2.65	2.67	2.70	2.72	2.74	2.77	2.79
23	2.74	2.76	2.79	2.81	2.83	2.86	2.88	2.91	2.93	2.96	2.98	3.01	3.03	3.06	3.08	3.11
24	3.06	3.09	3.11	3.14	3.16	3.19	3.22	3.24	3.27	3.30	3.32	3.35	3.38	3.40	3.43	3.46
25	3.41	3.44	3.46	3.49	3.52	3.55	3.58	3.60	3.63	3.66	3.69	3.72	3.75	3.78	3.81	3.84
26	3.78	3.81	3.84	3.87	3.90	3.93	3.96	3.99	4.02	4.05	4.08	4.11	4.14	4.17	4.20	4.23
27	4.17	4.20	4.23	4.26	4.29	4.32	4.35	4.38	4.42	4.45	4.48	4.51	4.54	4.58	4.61	4.64
28	4.58	4.61	4.64	4.68	4.71	4.74	4.78	4.81	4.84	4.88	4.91	4.94	4.98	5.01	5.05	5.08
29	5.02	5.05	5.09	5.12	5.16	5.19	5.23	5.26	5.30	5.33	5.37	5.41	5.44	5.48	5.52	5.55
30	5.49	5.53	5.56	5.60	5.64	5.68	5.71	5.75	5.79	5.83	5.87	5.90	5.94	5.98	6.02	6.06
31	5.98	6.02	6.06	6.10	6.14	6.18	6.22	6.26	6.30	6.34	6.38	6.42	6.46	6.50	6.54	6.58
32	6.50	6.54	6.58	6.62	6.66	6.70	6.74	6.78	6.82	6.86	6.90	6.94	6.98	7.03	7.07	7.11
33	7.07	7.11	7.15	7.19	7.24	7.28	7.32	7.36	7.41	7.45	7.49	7.53	7.58	7.62	7.66	7.71
34	7.66	7.70	7.74	7.79	7.83	7.87	7.92	7.96	8.01	8.05	8.09	8.14	8.18	8.23	8.27	8.32
35	8.27	8.31	8.36	8.40	8.45	8.49	8.54	8.58	8.63	8.67	8.72	8.76	8.81	8.86	8.90	8.95
36	8.90	8.95	8.99	9.04	9.09	9.13	9.18	9.23	9.27	9.32	9.37	9.42	9.46	9.51	9.56	9.61
37	9.56	9.60	9.65	9.70	9.75	9.80	9.84	9.89	9.94	9.99	10.04	10.09	10.14	10.19	10.24	10.29
38	10.24	10.29	10.34	10.39	10.44	10.49	10.54	10.59	10.64	10.69	10.74	10.79	10.84	10.89	10.94	10.99
39	10.94	10.99	11.04	11.09	11.14	11.19	11.24	11.29	11.34	11.39	11.44	11.49	11.54	11.59	11.64	11.69
40	11.69	11.74	11.79	11.84	11.89	11.94	12.00	12.05	12.10	12.15	12.20	12.25	12.30	12.35	12.40	12.45
41	12.50	12.55	12.60	12.65	12.70	12.76	12.81	12.86	12.91	12.96	13.01	13.06	13.11	13.16	13.21	13.26
42	13.36	13.41	13.46	13.51	13.56	13.61	13.66	13.71	13.76	13.81	13.86	13.91	13.96	14.01	14.06	14.11
43	14.22	14.27	14.32	14.37	14.42	14.47	14.52	14.57	14.62	14.67	14.72	14.77	14.82	14.87	14.92	14.97
44	15.08	15.13	15.18	15.23	15.28	15.33	15.38	15.43	15.48	15.53	15.58	15.63	15.68	15.73	15.78	15.83
45	15.94	15.99	16.04	16.09	16.14	16.19	16.24	16.29	16.34	16.39	16.44	16.49	16.54	16.59	16.64	16.69
46	16.80	16.85	16.90	16.95	17.00	17.05	17.10	17.15	17.20	17.25	17.30	17.35	17.40	17.45	17.50	17.55
47	17.66	17.71	17.76	17.81	17.86	17.91	17.96	18.01	18.06	18.11	18.16	18.21	18.26	18.31	18.36	18.41
48	18.52	18.57	18.62	18.67	18.72	18.77	18.82	18.87	18.92	18.97	19.02	19.07	19.12	19.17	19.22	19.27
49	19.38	19.43	19.48	19.53	19.58	19.63	19.68	19.73	19.78	19.83	19.88	19.93	19.98	20.03	20.08	20.13
50	20.24	20.29	20.34	20.39	20.44	20.49	20.54	20.59	20.64	20.69	20.74	20.79	20.84	20.89	20.94	20.99
51	21.04	21.09	21.14	21.19	21.24	21.29	21.34	21.39	21.44	21.49	21.54	21.59	21.64	21.69	21.74	21.79
52	21.84	21.89	21.94	21.99	22.04	22.09	22.14	22.19	22.24	22.29	22.34	22.39	22.44	22.49	22.54	22.59
53	22.64	22.69	22.74	22.79	22.84	22.89	22.94	22.99	23.04	23.09	23.14	23.19	23.24	23.29	23.34	23.39
54	23.44	23.49	23.54	23.59	23.64	23.69	23.74	23.79	23.84	23.89	23.94	23.99	24.04	24.09	24.14	24.19
55	24.24	24.29	24.34	24.39	24.44	24.49	24.54	24.59	24.64	24.69	24.74	24.79	24.84	24.89	24.94	24.99
56	25.04	25.09	25.14	25.19	25.24	25.29	25.34	25.39	25.44	25.49	25.54	25.59	25.64	25.69	25.74	25.79
57	25.84	25.89	25.94	25.99	26.04	26.09	26.14	26.19	26.24	26.29	26.34	26.39	26.44	26.49	26.54	26.59
58	26.64	26.69	26.74	26.79	26.84	26.89	26.94	26.99	27.04	27.09	27.14	27.19	27.24	27.29	27.34	27.39
59	27.44	27.49	27.54	27.59	27.64	27.69	27.74	27.79	27.84	27.89	27.94	27.99	28.04	28.09	28.14	28.19
60	28.24	28.29	28.34	28.39	28.44	28.49	28.54	28.59	28.64	28.69	28.74	28.79	28.84	28.89	28.94	28.99

* 1KIP=1,000 POUNDS

Table 31.--Log weights for scaling lengths of 4 to 32 feet: density index = 58 pounds per cubic foot

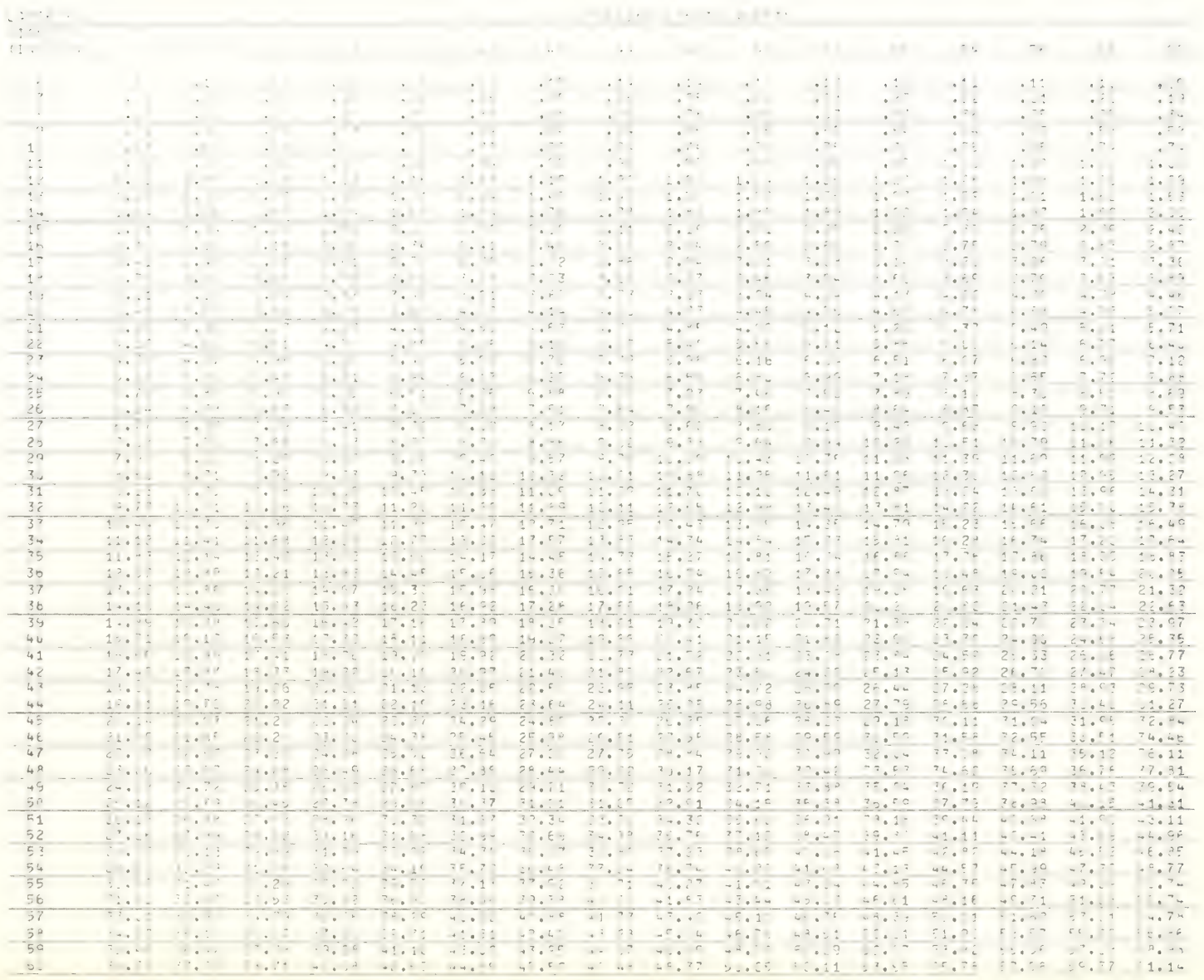
[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KIPS*) PER DENSITY INDEX=58

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20
6	.10	.10	.11	.11	.11	.12	.12	.13	.13	.14	.14	.15	.15	.16	.16	.16
7	.12	.12	.13	.13	.14	.14	.15	.15	.16	.16	.17	.17	.18	.18	.19	.19
8	.14	.15	.15	.16	.16	.17	.17	.18	.18	.19	.19	.20	.20	.21	.21	.22
9	.17	.17	.18	.18	.19	.19	.20	.20	.21	.21	.22	.22	.23	.23	.24	.25
10	.19	.20	.20	.21	.21	.22	.22	.23	.24	.24	.25	.25	.26	.27	.27	.28
11	.22	.23	.23	.24	.24	.25	.26	.26	.27	.28	.28	.29	.30	.30	.31	.32
12	.25	.26	.26	.27	.28	.28	.29	.30	.31	.31	.32	.33	.34	.34	.35	.36
13	.28	.29	.30	.30	.31	.32	.33	.34	.34	.35	.36	.37	.38	.39	.39	.41
14	.32	.33	.33	.34	.35	.36	.37	.38	.38	.39	.40	.41	.42	.43	.44	.45
15	.35	.36	.37	.38	.39	.40	.41	.42	.43	.44	.45	.46	.47	.48	.49	.50
16	.39	.40	.41	.42	.43	.44	.45	.46	.47	.48	.49	.50	.52	.53	.54	.55
17	.43	.44	.45	.46	.47	.48	.49	.50	.52	.53	.54	.55	.56	.58	.59	.61
18	.47	.48	.49	.50	.51	.53	.54	.55	.56	.58	.59	.60	.62	.63	.64	.67
19	.51	.52	.53	.55	.56	.57	.59	.60	.61	.63	.64	.66	.67	.68	.70	.73
20	.56	.57	.58	.59	.61	.62	.63	.65	.66	.68	.69	.71	.72	.74	.75	.78
21	.60	.62	.63	.64	.66	.67	.69	.70	.72	.73	.75	.76	.78	.80	.81	.84
22	.65	.67	.68	.70	.71	.73	.74	.76	.78	.79	.81	.83	.84	.86	.88	.91
23	.70	.72	.73	.75	.77	.78	.80	.82	.84	.85	.87	.89	.91	.93	.95	.98
24	.75	.77	.79	.81	.82	.84	.86	.88	.90	.92	.94	.96	.98	1.00	1.02	1.06
25	.81	.83	.85	.86	.88	.90	.92	.94	.96	.98	1.00	1.03	1.05	1.07	1.09	1.13
26	.87	.89	.90	.92	.94	.96	.98	1.01	1.03	1.05	1.07	1.10	1.12	1.14	1.17	1.21
27	.92	.94	.96	.98	1.00	1.02	1.05	1.07	1.09	1.12	1.14	1.16	1.19	1.21	1.24	1.28
28	.98	1.00	1.02	1.04	1.07	1.09	1.11	1.14	1.16	1.19	1.21	1.24	1.26	1.29	1.32	1.36
29	1.04	1.06	1.08	1.11	1.13	1.15	1.18	1.20	1.23	1.25	1.28	1.31	1.33	1.36	1.39	1.44
30	1.10	1.12	1.14	1.17	1.19	1.22	1.24	1.27	1.30	1.32	1.35	1.38	1.41	1.43	1.46	1.52
31	1.16	1.18	1.21	1.23	1.26	1.28	1.31	1.34	1.36	1.39	1.42	1.45	1.48	1.51	1.54	1.59
32	1.22	1.24	1.27	1.29	1.32	1.35	1.37	1.40	1.43	1.46	1.49	1.52	1.55	1.58	1.61	1.67
33	1.28	1.31	1.33	1.36	1.39	1.41	1.44	1.47	1.50	1.53	1.56	1.59	1.62	1.65	1.68	1.75
34	1.35	1.37	1.40	1.43	1.45	1.48	1.51	1.54	1.57	1.60	1.63	1.66	1.69	1.72	1.76	1.83
35	1.41	1.44	1.47	1.50	1.52	1.55	1.58	1.61	1.64	1.67	1.70	1.73	1.77	1.80	1.83	1.91
36	1.48	1.51	1.54	1.56	1.59	1.62	1.65	1.68	1.71	1.74	1.78	1.81	1.84	1.87	1.91	1.99
37	1.55	1.58	1.61	1.63	1.66	1.69	1.72	1.75	1.79	1.82	1.85	1.88	1.92	1.95	1.99	2.07
38	1.62	1.65	1.68	1.71	1.74	1.77	1.80	1.83	1.86	1.89	1.93	1.96	2.00	2.03	2.07	2.15
39	1.69	1.72	1.75	1.78	1.81	1.84	1.87	1.91	1.94	1.97	2.01	2.04	2.08	2.11	2.15	2.24
40	1.76	1.79	1.82	1.85	1.88	1.92	1.95	1.98	2.02	2.05	2.09	2.12	2.16	2.20	2.24	2.32
41	1.83	1.86	1.90	1.93	1.96	1.99	2.03	2.06	2.10	2.13	2.17	2.21	2.24	2.28	2.32	2.41
42	1.91	1.94	1.97	2.01	2.04	2.07	2.11	2.14	2.18	2.22	2.25	2.29	2.33	2.37	2.41	2.50
43	1.98	2.02	2.05	2.08	2.12	2.15	2.19	2.23	2.26	2.30	2.34	2.38	2.42	2.46	2.50	2.59
44	2.06	2.09	2.13	2.16	2.20	2.24	2.27	2.31	2.35	2.39	2.43	2.47	2.51	2.55	2.59	2.69
45	2.14	2.17	2.21	2.24	2.28	2.32	2.36	2.40	2.44	2.48	2.52	2.56	2.60	2.64	2.69	2.78
46	2.22	2.25	2.29	2.33	2.37	2.40	2.44	2.48	2.52	2.57	2.61	2.65	2.69	2.74	2.78	2.88
47	2.30	2.33	2.37	2.41	2.45	2.49	2.53	2.57	2.61	2.65	2.70	2.74	2.78	2.83	2.87	2.98
48	2.38	2.41	2.45	2.49	2.53	2.57	2.61	2.66	2.70	2.74	2.78	2.83	2.87	2.92	2.96	3.07
49	2.46	2.50	2.54	2.58	2.62	2.66	2.70	2.74	2.79	2.83	2.87	2.92	2.96	3.01	3.06	3.17
50	2.54	2.58	2.62	2.66	2.70	2.74	2.79	2.83	2.87	2.92	2.96	3.01	3.06	3.10	3.15	3.26
51	2.62	2.66	2.70	2.74	2.79	2.83	2.87	2.92	2.96	3.01	3.05	3.10	3.15	3.20	3.25	3.36
52	2.71	2.75	2.79	2.83	2.87	2.92	2.96	3.01	3.05	3.10	3.15	3.19	3.24	3.29	3.34	3.46
53	2.79	2.83	2.87	2.92	2.96	3.00	3.05	3.10	3.14	3.19	3.24	3.29	3.34	3.39	3.44	3.56
54	2.88	2.92	2.96	3.00	3.05	3.09	3.14	3.19	3.24	3.29	3.33	3.38	3.43	3.48	3.54	3.66
55	2.96	3.00	3.05	3.09	3.14	3.18	3.23	3.28	3.33	3.38	3.43	3.48	3.53	3.58	3.63	3.76
56	3.05	3.09	3.14	3.18	3.23	3.28	3.33	3.38	3.43	3.48	3.53	3.58	3.63	3.68	3.74	3.86
57	3.14	3.18	3.23	3.27	3.32	3.37	3.42	3.47	3.52	3.57	3.62	3.68	3.73	3.78	3.84	3.97
58	3.23	3.27	3.32	3.37	3.41	3.46	3.51	3.57	3.62	3.67	3.72	3.77	3.83	3.88	3.94	4.07
59	3.32	3.36	3.41	3.46	3.51	3.56	3.61	3.66	3.71	3.77	3.82	3.87	3.93	3.98	4.04	4.17
60	3.41	3.46	3.50	3.55	3.60	3.65	3.71	3.76	3.81	3.87	3.92	3.97	4.03	4.09	4.14	4.28
61	3.50	3.55	3.60	3.65	3.70	3.75	3.80	3.86	3.91	3.97	4.02	4.08	4.13	4.19	4.25	4.38
62	3.59	3.64	3.69	3.74	3.79	3.85	3.90	3.96	4.01	4.07	4.12	4.18	4.24	4.30	4.35	4.49
63	3.68	3.73	3.78	3.84	3.89	3.94	4.00	4.06	4.11	4.17	4.23	4.28	4.34	4.40	4.46	4.60
64	3.78	3.83	3.88	3.93	3.99	4.04	4.10	4.16	4.21	4.27	4.33	4.39	4.45	4.51	4.57	4.71
65	3.87	3.92	3.98	4.03	4.09	4.14	4.20	4.26	4.32	4.38	4.43	4.49	4.55	4.62	4.68	4.82
66	3.97	4.02	4.08	4.13	4.19	4.25	4.31	4.36	4.42	4.48	4.54	4.60	4.66	4.72	4.78	4.93
67	4.06	4.12	4.17	4.23	4.29	4.35	4.41	4.47	4.53	4.59	4.65	4.71	4.77	4.83	4.89	5.04
68	4.16	4.22	4.27	4.33	4.39	4.45	4.51	4.57	4.63	4.69	4.75	4.81	4.88	4.94	5.00	5.15
69	4.26	4.32	4.37	4.43	4.49	4.55	4.61	4.67	4.73	4.80	4.86	4.92	4.98	5.05	5.11	5.27
70	4.36	4.42	4.47	4.53	4.59	4.65	4.72	4.78	4.84	4.90	4.96	5.03	5.09	5.15	5.22	5.38
71	4.46	4.52	4.57	4.63	4.70	4.76	4.82	4.88	4.94	5.01	5.07	5.13	5.20	5.26	5.33	5.49
72	4.56	4.62	4.68	4.74	4.80	4.86	4.92	4.99	5.05	5.11	5.18	5.24	5.31	5.37	5.44	5.60
73	4.66	4.72	4.78	4.84	4.90	4.96	5.03	5.09	5.15	5.22	5.28	5.35	5.41	5.48	5.55	5.71
74	4.76	4.82	4.88	4.94	5.00	5.07	5.13	5.19	5.26	5.32	5.39	5.45	5.52	5.59	5.66	5.82
75	4.86	4.92	4.98	5.04	5.11	5.17	5.23	5.30	5.36	5.43	5.49	5.56	5.63	5.70	5.77	5.93
76	4.96	5.02	5.08	5.15	5.21	5.27	5.34	5.40	5.47	5.53	5.60	5.67	5.74	5.80	5.87	6.04
77	5.06	5.12	5.19	5.25	5.31	5.38	5.44	5.51	5.57	5.64	5.71	5.77	5.84	5.91	5.98	6.15
78	5.16	5.23	5.29	5.35	5.42	5.48	5.55	5.61	5.68	5.75	5.81	5.88	5.95	6.02	6.09	6.26
79	5.27	5.33	5.39	5.46	5.52	5.59	5.65	5.72	5.78	5.85	5.92	5.99	6.06	6.13	6.20	6.37
80	5.37	5.43	5.50	5.56	5.63	5.69	5.76	5.82	5.89	5.96	6.03	6.10	6.17	6.24	6.31	6.48
81	5.47	5.54	5.60	5.67	5.73	5.80	5.86	5.93	6.00	6.07	6.14	6.21	6.28	6.35	6.42	6.60
82	5.58	5.64	5.71	5.77	5.84	5.90	5.97	6.04	6.11	6.18	6.25	6.32	6.39	6.46	6.53	6.71
83	5.68	5.75	5.81	5.88	5.94	6.01	6.08	6.15	6.22	6.29	6.36	6.43	6.50	6.57	6.65	6.83
84	5.79	5.85	5.92	5.98	6.05	6.12	6.19	6.26	6.33	6.40	6.47	6.54	6.61	6.69	6.76	6.94
85	5.89	5.96	6.02	6.09	6.16	6.23	6.30	6.37	6.44	6.51	6.58	6.65	6.73	6.80	6.87	7.06
86	6.00	6.06	6.13	6.20	6.27	6.34	6.41	6.48	6.55	6.62	6.70	6.77	6.84	6.91	6.99	7.17
87	6.10	6.17	6.24	6.31	6.38	6.45	6.52	6.59	6.66	6.74	6.81	6.88	6.96	7.03	7.10	7.29
88	6.21	6.28	6.35	6.42	6.49	6.56	6.63	6.70	6.78	6.85	6.92	7.00	7.07	7.14	7.22	7.40
89	6.32	6.39	6.46	6.53	6.60	6.67	6.74	6.82	6.89	6.96	7.04	7.11	7.19	7.26	7.34	7.52
90	6.43	6.50	6.57	6.64	6.71	6.78	6.86	6.93	7.00	7.08	7.15	7.23	7.30	7.38	7.45	7.64
91	6.54	6.61	6.68	6.75	6.82	6.90	6.97	7.04	7.12	7.19	7.27	7.34	7.42	7.50	7.57	7.76
92	6.65	6.72	6.79	6.86	6.94	7.01	7.08	7.16	7.23	7.31	7.38	7.46	7.54	7.61	7.69	7.88
93	6.76	6.83	6.90	6.98	7.05	7.12	7.20	7.27	7.35	7.42	7.50	7.58	7.65	7.73	7.81	8.00
94	6.87	6.94	7.01	7.09	7.16	7.24	7.31	7.39	7.46	7.54	7.62	7.69	7.77	7.85	7.93	8.12
95	6.98	7.05	7.13	7.20	7.28	7.35	7.43	7.50	7.58	7.66	7.73	7.81	7.89	7.97	8.05	8.24
96	7.09	7.17	7.24	7.32	7.39	7.47	7.54	7.62	7.70	7.77	7.85	7.93	8.01	8.09	8.17	8.36
97	7.21	7.28	7.35	7.43	7.51	7.58	7.66	7.74	7.81	7.89	7.97	8.05	8.13	8.21	8.29	8.48
98	7.32	7.39	7.47	7.54	7.62	7.70	7.78	7.85	7.93	8.01	8.09	8.17	8.25	8.33	8.41	8.61
99	7.43	7.51	7.58	7.66	7.74	7.82	7.89	7.97	8.05	8.13	8.21	8.29	8.37	8.45	8.53	8.73
100	7.55	7.62	7.70	7.78	7.85	7.93	8.01	8.09	8.17	8.25	8.33	8.41	8.49	8.57	8.65	8.85

Table 32.--Log weights for scaling lengths of 34 to 60 feet: density index = 58 pounds per cubic foot

(Assumed taper of 1 inch per 4 feet, trim allowance of 1 inch per 4 feet)



* 1KIP=1 ... POUN...

Table 33.--Log weights for scaling lengths of 4 to 32 feet: density index = 60 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

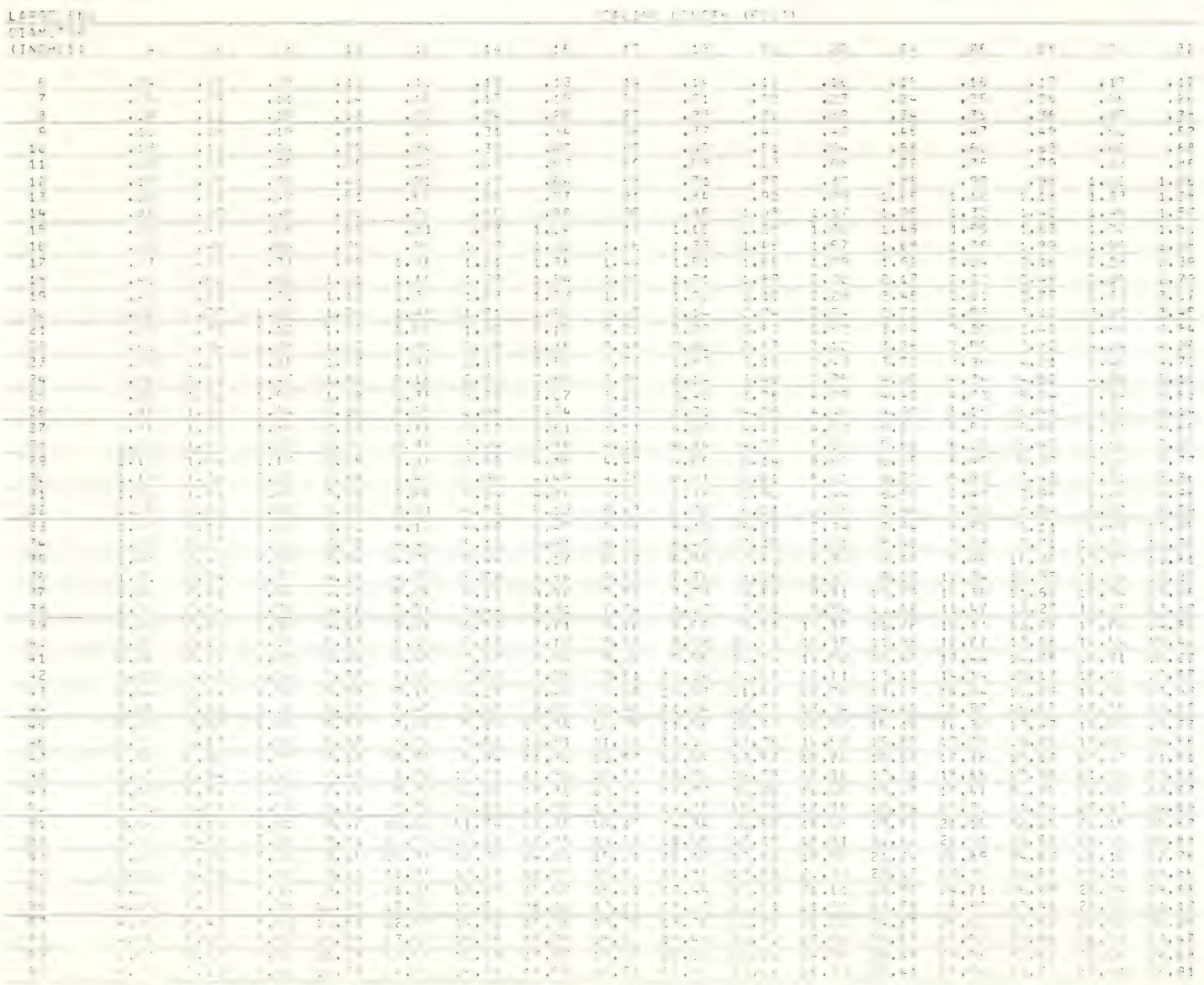


Table 34.--Log weights for scaling lengths of 34 to 60 feet: density index = 60 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

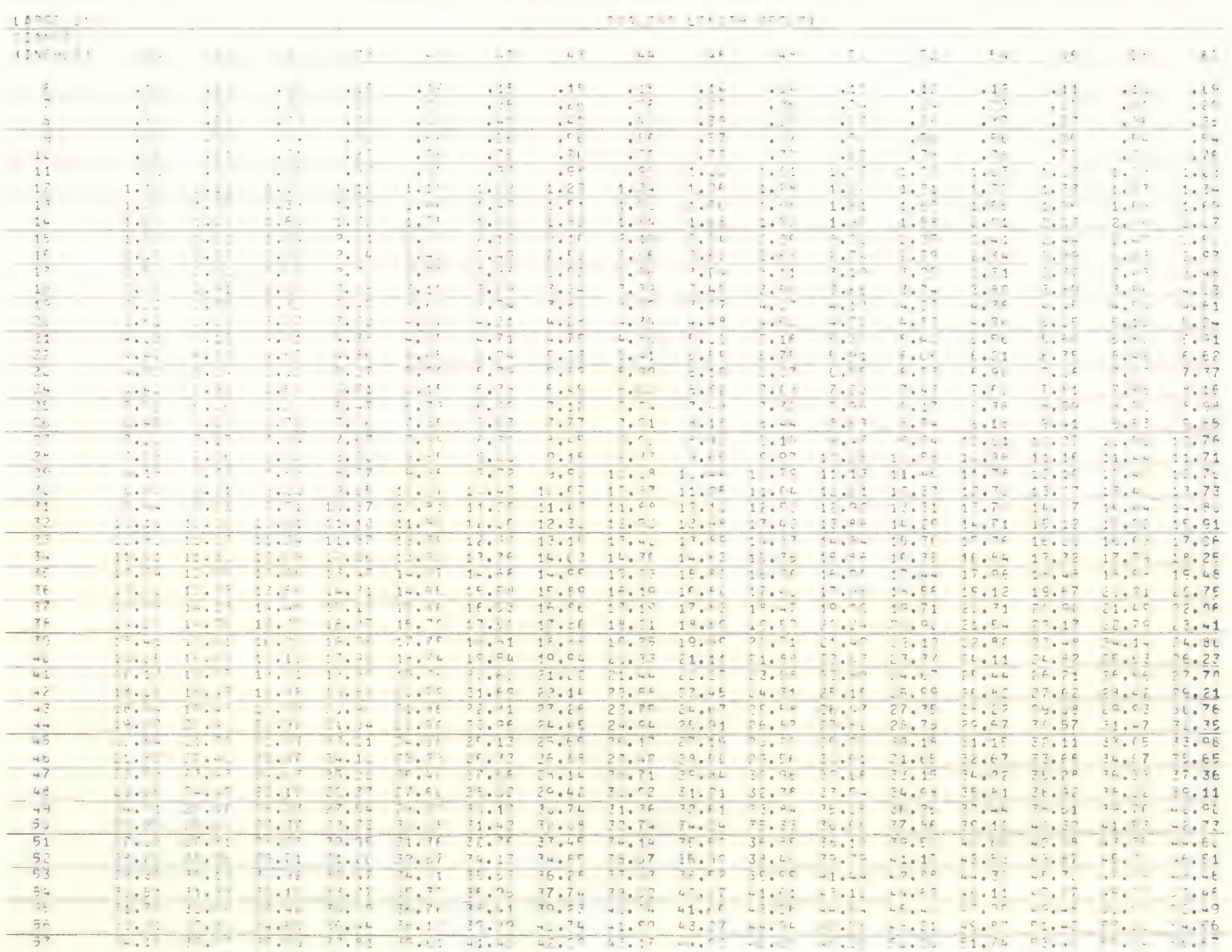


Table 35.--Log weights for scaling lengths of 4 to 32 feet: density index = 62 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

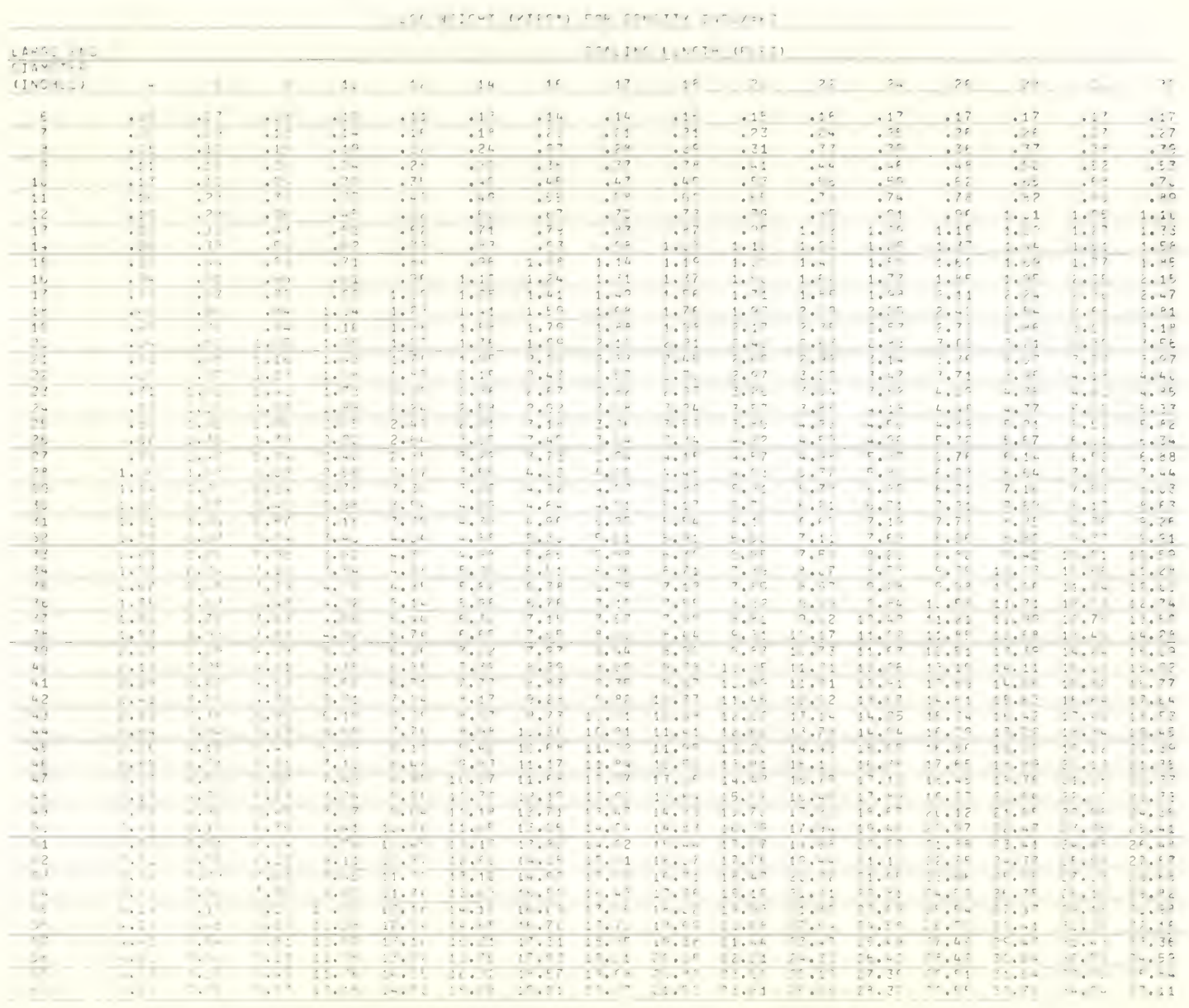
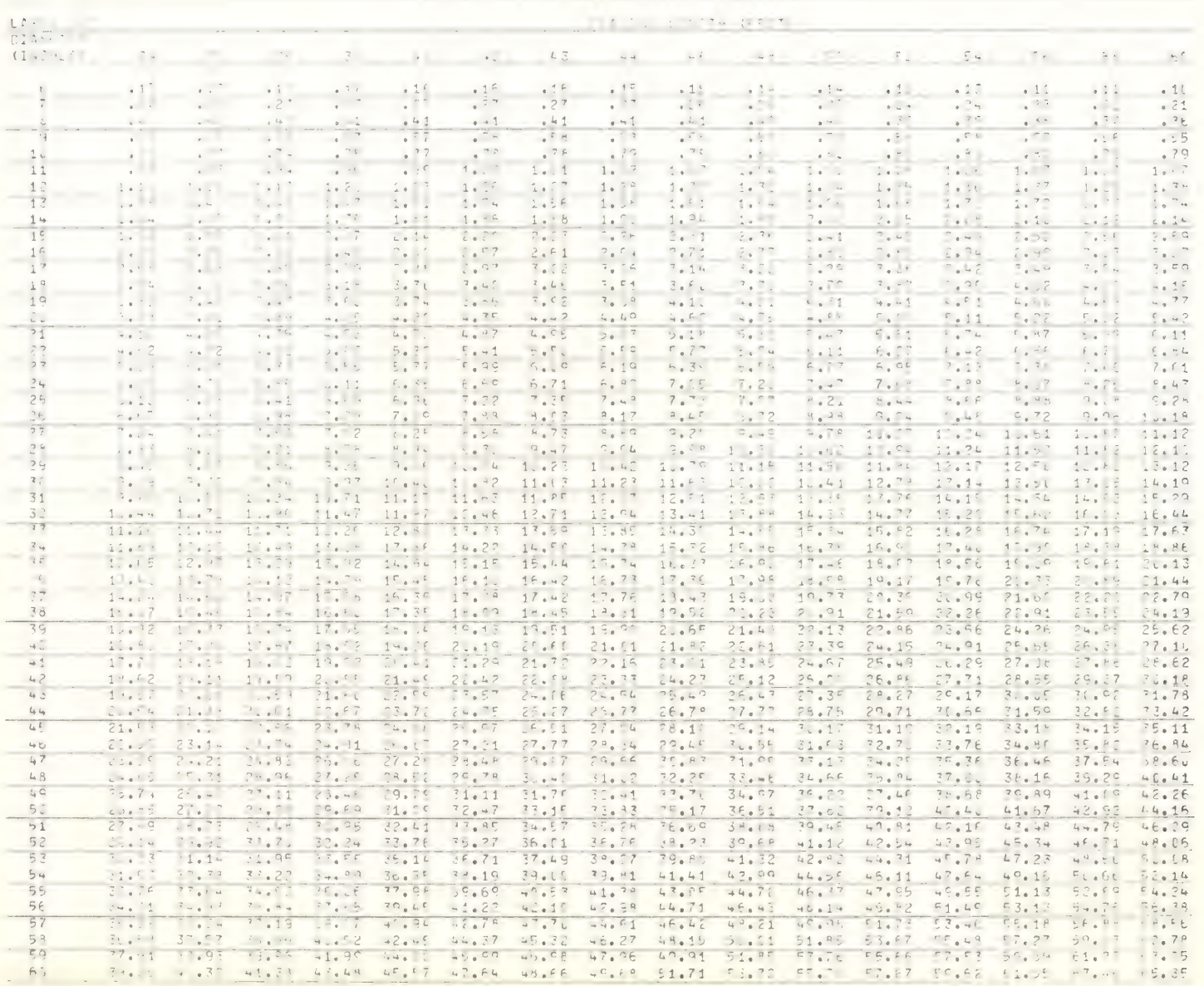


Table 36.--Log weights for scaling lengths of 34 to 60 feet: density index = 62 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]



* 1KIP=1000 POUNDS

Table 37.--Log weights for scaling lengths of 4 to 32 feet: density index = 64 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (POUNDS) FOR DENSITY INDEX=64

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	8	12	16	20	24	28	32								
6	.13	.27	.40	.53	.66	.79	.92	1.06								
7	.18	.36	.54	.72	.90	1.08	1.26	1.44								
8	.23	.47	.70	.94	1.17	1.41	1.64	1.88								
9	.30	.59	.89	1.19	1.48	1.78	2.08	2.37								
10	.36	.73	1.09	1.46	1.82	2.19	2.55	2.92								
11	.44	.88	1.32	1.76	2.20	2.64	3.08	3.52								
12	.52	1.04	1.56	2.08	2.60	3.12	3.64	4.16								
13	.61	1.22	1.83	2.44	3.05	3.66	4.27	4.88								
14	.70	1.41	2.11	2.82	3.52	4.23	4.93	5.64								
15	.81	1.61	2.42	3.22	4.03	4.83	5.64	6.44								
16	.91	1.83	2.74	3.65	4.57	5.48	6.39	7.31								
17	1.03	2.06	3.09	4.12	5.15	6.18	7.21	8.24								
18	1.15	2.30	3.45	4.60	5.75	6.90	8.05	9.20								
19	1.28	2.56	3.84	5.12	6.40	7.68	8.96	10.24								
20	1.42	2.84	4.25	5.67	7.09	8.51	9.92	11.34								
21	1.56	3.13	4.69	6.25	7.82	9.38	10.94	12.51								
22	1.72	3.44	5.16	6.88	8.60	10.32	12.04	13.76								
23	1.88	3.76	5.64	7.52	9.40	11.28	13.16	15.04								
24	2.05	4.10	6.15	8.20	10.25	12.30	14.35	16.40								
25	2.23	4.46	6.69	8.92	11.15	13.38	15.61	17.84								
26	2.42	4.83	7.25	9.66	12.08	14.49	16.91	19.32								
27	2.61	5.22	7.83	10.44	13.05	15.66	18.27	20.88								
28	2.81	5.63	8.44	11.25	14.06	16.88	19.69	22.50								
29	3.02	6.05	9.07	12.09	15.11	18.14	21.16	24.18								
30	3.24	6.48	9.72	12.96	16.20	19.44	22.68	25.92								
31	3.47	6.93	10.40	13.86	17.33	20.79	24.26	27.72								
32	3.70	7.40	11.10	14.80	18.50	22.20	25.90	29.60								
33	3.94	7.88	11.82	15.76	19.70	23.64	27.58	31.52								
34	4.19	8.38	12.57	16.76	20.95	25.14	29.33	33.52								
35	4.45	8.90	13.35	17.80	22.25	26.70	31.15	35.60								
36	4.72	9.44	14.16	18.88	23.60	28.32	33.04	37.76								
37	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00								
38	5.29	10.58	15.87	21.16	26.45	31.74	37.03	42.32								
39	5.59	11.18	16.77	22.36	27.95	33.54	39.13	44.72								
40	5.90	11.80	17.70	23.60	29.50	35.40	41.30	47.20								
41	6.22	12.44	18.66	24.88	31.10	37.32	43.54	49.76								
42	6.55	13.10	19.65	26.20	32.75	39.30	45.85	52.40								
43	6.89	13.78	20.67	27.56	34.45	41.34	48.23	55.12								
44	7.24	14.48	21.72	28.96	36.20	43.44	50.68	57.92								
45	7.60	15.20	22.80	30.40	38.00	45.60	53.20	60.80								
46	7.97	15.94	23.91	31.88	39.85	47.82	55.79	63.76								
47	8.35	16.70	25.05	33.40	41.75	50.10	58.45	66.80								
48	8.74	17.48	26.22	34.96	43.70	52.44	61.18	69.92								
49	9.14	18.28	27.42	36.56	45.70	54.84	63.98	73.12								
50	9.55	19.10	28.65	38.20	47.75	57.30	66.85	76.40								
51	9.97	19.94	29.91	39.88	49.85	59.82	69.79	79.76								
52	10.40	20.80	31.20	41.60	52.00	62.40	72.80	83.20								
53	10.84	21.68	32.52	43.36	54.20	65.04	75.88	86.72								
54	11.29	22.58	33.87	45.16	56.45	67.74	79.03	90.32								
55	11.75	23.50	35.25	47.00	58.75	70.50	82.25	94.00								
56	12.22	24.44	36.66	48.88	61.10	73.32	85.54	97.76								
57	12.70	25.40	38.10	50.80	63.50	76.20	88.90	101.60								
58	13.19	26.38	39.57	52.76	65.95	79.14	92.33	105.52								
59	13.69	27.38	41.07	54.76	68.45	82.14	95.83	109.52								
60	14.20	28.40	42.60	56.80	71.00	85.20	99.40	113.60								

Table 38.--Log weights for scaling lengths of 34 to 60 feet: density index = 64 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

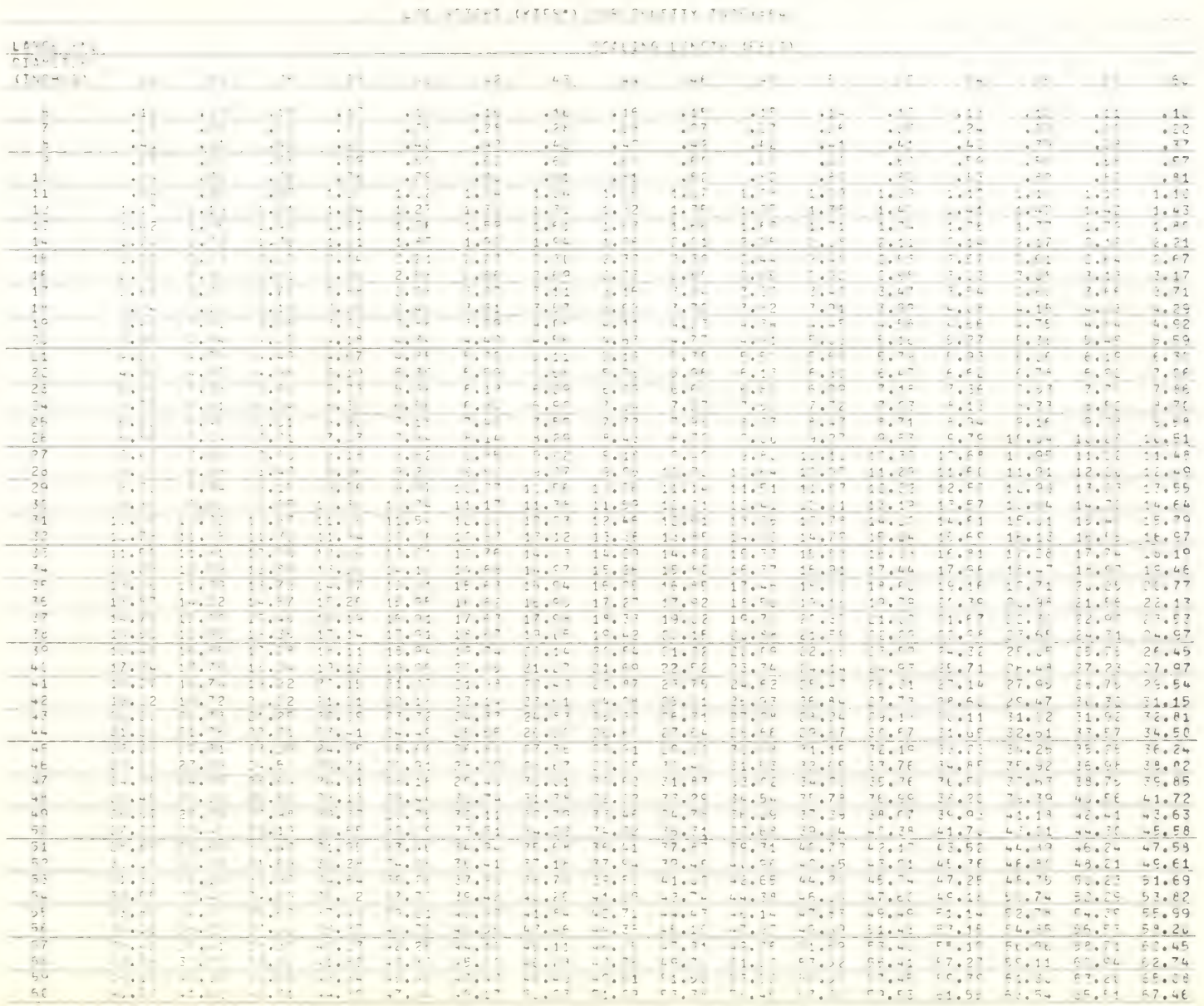


Table 39.--Log weights for scaling lengths of 4 to 32 feet: density index = 66 pounds per cubic foot

{Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet}

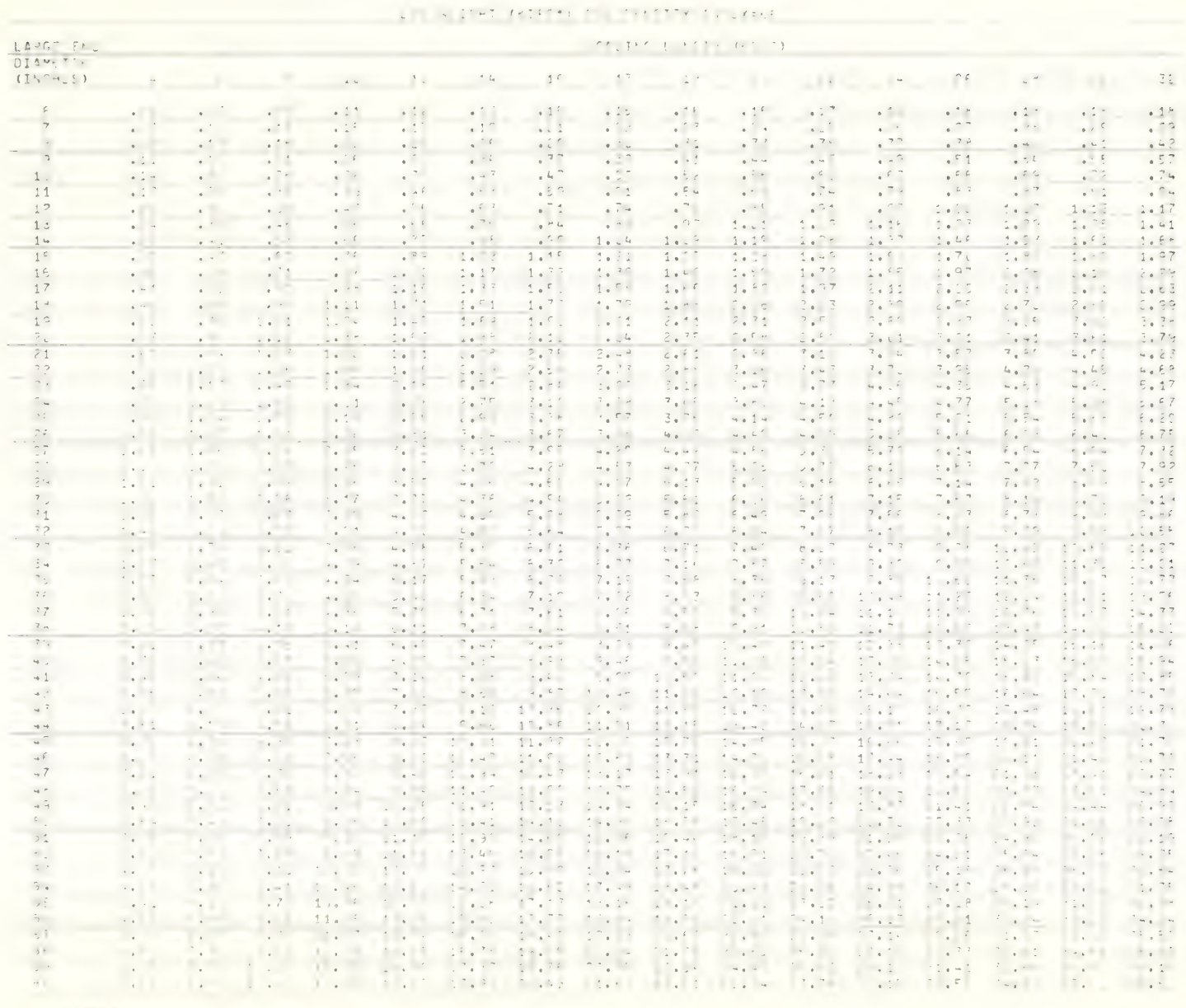


Table 40.--Log weights for scaling lengths of 34 to 60 feet: density index = 66 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KIPS*) FOR DENSITY INDEX=66

LARGE END DIAM TIB (INCHES)	SCALING LENGTH (FEET)															
	34	36	38	40	42	44	46	48	50	52	54	56	58	60		
6	.16	.16	.16	.17	.17	.17	.17	.18	.18	.18	.19	.19	.19	.19	.20	.20
7	.21	.21	.22	.22	.23	.23	.24	.24	.25	.25	.26	.26	.27	.27	.28	.28
8	.27	.28	.28	.29	.29	.30	.30	.31	.31	.32	.32	.33	.33	.34	.34	.35
9	.34	.35	.35	.36	.37	.37	.38	.38	.39	.40	.40	.41	.41	.42	.42	.43
10	.41	.42	.43	.44	.45	.46	.47	.47	.48	.49	.50	.50	.51	.52	.53	.53
11	.50	.51	.52	.53	.54	.55	.56	.57	.58	.59	.60	.61	.62	.63	.64	.65
12	1.21	1.23	1.24	1.26	1.27	1.29	1.30	1.32	1.33	1.35	1.36	1.38	1.39	1.41	1.42	1.44
13	1.47	1.49	1.51	1.53	1.55	1.57	1.59	1.61	1.63	1.65	1.67	1.69	1.71	1.73	1.75	1.77
14	1.76	1.78	1.81	1.83	1.85	1.88	1.90	1.93	1.95	1.98	2.00	2.03	2.05	2.08	2.10	2.13
15	2.08	2.11	2.14	2.17	2.20	2.23	2.26	2.29	2.32	2.35	2.38	2.41	2.44	2.47	2.50	2.53
16	2.43	2.47	2.50	2.54	2.57	2.61	2.64	2.68	2.71	2.75	2.78	2.82	2.85	2.89	2.92	2.96
17	2.83	2.87	2.91	2.95	2.99	3.03	3.07	3.11	3.15	3.19	3.23	3.27	3.31	3.35	3.39	3.43
18	3.28	3.32	3.37	3.41	3.46	3.50	3.55	3.59	3.64	3.68	3.73	3.77	3.82	3.86	3.91	3.95
19	3.77	3.82	3.87	3.92	3.97	4.02	4.07	4.12	4.17	4.22	4.27	4.32	4.37	4.42	4.47	4.52
20	4.32	4.37	4.43	4.48	4.53	4.59	4.64	4.70	4.75	4.81	4.86	4.92	4.97	5.03	5.08	5.14
21	4.93	4.99	5.05	5.11	5.17	5.23	5.29	5.35	5.41	5.47	5.53	5.59	5.65	5.71	5.77	5.83
22	5.61	5.67	5.74	5.80	5.86	5.93	5.99	6.05	6.12	6.18	6.25	6.31	6.38	6.44	6.51	6.57
23	6.34	6.41	6.48	6.55	6.62	6.68	6.75	6.82	6.89	6.96	7.03	7.10	7.17	7.24	7.31	7.38
24	7.12	7.19	7.27	7.34	7.41	7.48	7.56	7.63	7.70	7.78	7.85	7.93	8.00	8.07	8.15	8.22
25	7.97	8.05	8.13	8.21	8.29	8.37	8.45	8.53	8.61	8.69	8.77	8.85	8.93	9.01	9.09	9.17
26	8.89	8.98	9.07	9.16	9.25	9.34	9.43	9.52	9.61	9.70	9.79	9.88	9.97	10.06	10.15	10.24
27	9.93	10.03	10.13	10.23	10.33	10.43	10.53	10.63	10.73	10.83	10.93	11.03	11.13	11.23	11.33	11.43
28	11.04	11.15	11.26	11.37	11.48	11.59	11.70	11.81	11.92	12.03	12.14	12.25	12.36	12.47	12.58	12.69
29	12.25	12.37	12.49	12.61	12.73	12.85	12.97	13.09	13.21	13.33	13.45	13.57	13.69	13.81	13.93	14.05
30	13.53	13.66	13.79	13.92	14.05	14.18	14.31	14.44	14.57	14.70	14.83	14.96	15.09	15.22	15.35	15.48
31	14.91	15.05	15.19	15.33	15.47	15.61	15.75	15.89	16.03	16.17	16.31	16.45	16.59	16.73	16.87	17.01
32	16.42	16.57	16.72	16.87	17.02	17.17	17.32	17.47	17.62	17.77	17.92	18.07	18.22	18.37	18.52	18.67
33	18.07	18.23	18.39	18.55	18.71	18.87	19.03	19.19	19.35	19.51	19.67	19.83	19.99	20.15	20.31	20.47
34	19.78	19.95	20.12	20.29	20.46	20.63	20.80	20.97	21.14	21.31	21.48	21.65	21.82	21.99	22.16	22.33
35	21.56	21.74	21.92	22.10	22.28	22.46	22.64	22.82	23.00	23.18	23.36	23.54	23.72	23.90	24.08	24.26
36	23.41	23.60	23.79	23.98	24.17	24.36	24.55	24.74	24.93	25.12	25.31	25.50	25.69	25.88	26.07	26.26
37	25.32	25.52	25.72	25.92	26.12	26.32	26.52	26.72	26.92	27.12	27.32	27.52	27.72	27.92	28.12	28.32
38	27.30	27.51	27.72	27.93	28.14	28.35	28.56	28.77	28.98	29.19	29.40	29.61	29.82	30.03	30.24	30.45
39	29.34	29.56	29.78	30.00	30.22	30.44	30.66	30.88	31.10	31.32	31.54	31.76	31.98	32.20	32.42	32.64
40	31.45	31.68	31.91	32.14	32.37	32.60	32.83	33.06	33.29	33.52	33.75	33.98	34.21	34.44	34.67	34.90
41	33.64	33.88	34.12	34.36	34.60	34.84	35.08	35.32	35.56	35.80	36.04	36.28	36.52	36.76	37.00	37.24
42	35.91	36.16	36.41	36.66	36.91	37.16	37.41	37.66	37.91	38.16	38.41	38.66	38.91	39.16	39.41	39.66
43	38.27	38.53	38.79	39.05	39.31	39.57	39.83	40.09	40.35	40.61	40.87	41.13	41.39	41.65	41.91	42.17
44	40.73	41.00	41.27	41.54	41.81	42.08	42.35	42.62	42.89	43.16	43.43	43.70	43.97	44.24	44.51	44.78
45	43.29	43.57	43.85	44.13	44.41	44.69	44.97	45.25	45.53	45.81	46.09	46.37	46.65	46.93	47.21	47.49
46	45.96	46.25	46.54	46.83	47.12	47.41	47.70	47.99	48.28	48.57	48.86	49.15	49.44	49.73	50.02	50.31
47	48.74	49.04	49.34	49.64	49.94	50.24	50.54	50.84	51.14	51.44	51.74	52.04	52.34	52.64	52.94	53.24
48	51.64	51.95	52.26	52.57	52.88	53.19	53.50	53.81	54.12	54.43	54.74	55.05	55.36	55.67	55.98	56.29
49	54.67	54.99	55.31	55.63	55.95	56.27	56.59	56.91	57.23	57.55	57.87	58.19	58.51	58.83	59.15	59.47
50	57.83	58.16	58.49	58.82	59.15	59.48	59.81	60.14	60.47	60.80	61.13	61.46	61.79	62.12	62.45	62.78
51	61.13	61.47	61.81	62.15	62.49	62.83	63.17	63.51	63.85	64.19	64.53	64.87	65.21	65.55	65.89	66.23
52	64.57	64.92	65.27	65.62	65.97	66.32	66.67	67.02	67.37	67.72	68.07	68.42	68.77	69.12	69.47	69.82
53	68.15	68.51	68.87	69.23	69.59	69.95	70.31	70.67	71.03	71.39	71.75	72.11	72.47	72.83	73.19	73.55
54	71.87	72.24	72.61	72.98	73.35	73.72	74.09	74.46	74.83	75.20	75.57	75.94	76.31	76.68	77.05	77.42
55	75.74	76.12	76.50	76.88	77.26	77.64	78.02	78.40	78.78	79.16	79.54	79.92	80.30	80.68	81.06	81.44
56	79.76	80.15	80.54	80.93	81.32	81.71	82.10	82.49	82.88	83.27	83.66	84.05	84.44	84.83	85.22	85.61
57	83.94	84.34	84.74	85.14	85.54	85.94	86.34	86.74	87.14	87.54	87.94	88.34	88.74	89.14	89.54	89.94
58	88.29	88.70	89.11	89.52	89.93	90.34	90.75	91.16	91.57	91.98	92.39	92.80	93.21	93.62	94.03	94.44
59	92.81	93.23	93.65	94.07	94.49	94.91	95.33	95.75	96.17	96.59	97.01	97.43	97.85	98.27	98.69	99.11
60	97.50	97.93	98.36	98.79	99.22	99.65	100.08	100.51	100.94	101.37	101.80	102.23	102.66	103.09	103.52	103.95

* 1KIP=1,000 POUNDS

Table 41.--Log weights for scaling lengths of 4 to 32 feet: density index = 68 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KIPS*) FOR DENSITY INDEX=68

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
6	.08	.09	.09	.11	.12	.14	.15	.16	.16	.17	.18	.18	.19	.19	.19	.19
7	.09	.11	.13	.15	.18	.20	.22	.23	.23	.25	.26	.27	.28	.29	.29	.31
8	.09	.11	.17	.21	.24	.27	.31	.31	.32	.34	.36	.38	.40	.41	.42	.43
9	.12	.17	.22	.26	.31	.35	.39	.42	.42	.45	.48	.51	.53	.55	.57	.59
10	.14	.21	.27	.32	.39	.44	.49	.51	.53	.56	.60	.63	.66	.72	.74	.77
11	.17	.25	.33	.41	.48	.54	.61	.63	.66	.70	.77	.81	.86	.90	.94	.97
12	.21	.31	.43	.49	.57	.65	.77	.77	.80	.87	.94	1.00	1.06	1.11	1.16	1.20
13	.25	.36	.47	.58	.68	.78	.87	.91	.96	1.04	1.12	1.20	1.27	1.33	1.40	1.45
14	.29	.42	.53	.64	.75	.91	1.02	1.07	1.13	1.22	1.32	1.41	1.50	1.58	1.66	1.73
15	.33	.47	.64	.77	.92	1.06	1.19	1.25	1.31	1.43	1.54	1.65	1.75	1.85	1.95	2.03
16	.38	.51	.73	.89	1.06	1.21	1.36	1.47	1.56	1.64	1.77	1.91	2.02	2.14	2.25	2.36
17	.42	.57	.80	1.01	1.20	1.38	1.56	1.67	1.77	1.87	2.02	2.17	2.32	2.45	2.58	2.71
18	.47	.64	.87	1.14	1.35	1.55	1.75	1.84	1.94	2.10	2.28	2.46	2.63	2.79	2.94	3.08
19	.52	.70	1.00	1.26	1.51	1.74	1.96	2.07	2.17	2.32	2.51	2.71	2.90	3.06	3.22	3.38
20	.57	.77	1.07	1.42	1.68	1.94	2.18	2.30	2.42	2.58	2.80	3.01	3.21	3.41	3.58	3.75
21	.63	.87	1.17	1.57	1.86	2.14	2.40	2.55	2.68	2.86	3.10	3.34	3.56	3.77	3.96	4.15
22	.72	.96	1.29	1.73	2.04	2.36	2.67	2.82	2.96	3.16	3.43	3.69	3.93	4.17	4.38	4.59
23	.79	1.06	1.43	1.86	2.20	2.50	2.83	3.00	3.15	3.37	3.65	3.93	4.19	4.44	4.67	4.89
24	.86	1.17	1.57	2.04	2.41	2.82	3.21	3.38	3.56	3.81	4.13	4.45	4.74	5.03	5.29	5.54
25	.93	1.26	1.71	2.25	2.67	3.08	3.49	3.68	3.88	4.16	4.52	4.86	5.19	5.50	5.79	6.06
26	1.00	1.36	1.87	2.44	2.89	3.34	3.78	4.00	4.21	4.52	4.90	5.28	5.63	5.97	6.28	6.58
27	1.08	1.51	2.10	2.80	3.13	3.61	4.09	4.32	4.55	4.88	5.29	5.69	6.07	6.44	6.78	7.10
28	1.17	1.73	2.29	2.83	3.37	3.90	4.41	4.66	4.91	5.27	5.69	6.13	6.54	6.94	7.31	8.16
29	1.27	1.96	2.46	3.05	3.62	4.19	4.74	5.02	5.29	5.67	6.12	6.59	7.03	7.46	7.86	8.23
30	1.34	1.96	2.63	3.26	3.88	4.49	5.09	5.38	5.67	6.08	6.57	7.07	7.54	8.00	8.43	8.83
31	1.47	2.13	2.82	3.49	4.15	4.80	5.44	5.76	6.07	6.50	7.02	7.56	8.06	8.55	9.01	10.16
32	1.63	2.33	2.72	4.43	5.13	5.81	6.45	6.82	7.19	7.70	8.31	8.94	9.54	10.12	10.67	11.19
33	1.67	2.42	3.20	3.97	4.72	5.46	6.21	6.56	6.91	7.62	8.32	9.16	9.67	10.33	10.93	11.51
34	1.77	2.57	3.40	4.21	5.02	5.81	6.60	6.97	7.35	8.11	8.85	9.54	10.30	11.00	11.65	12.27
35	1.87	2.72	3.60	4.47	5.32	6.17	6.99	7.40	7.81	8.61	9.40	10.18	10.94	11.69	12.43	13.16
36	1.98	2.88	3.81	4.73	5.64	6.53	7.41	7.85	8.28	9.13	9.97	10.81	11.61	12.41	13.20	13.97
37	2.09	3.04	4.02	5.00	5.97	6.91	7.84	8.31	8.76	9.66	10.55	11.43	12.29	13.15	13.98	14.81
38	2.19	3.20	4.23	5.29	6.31	7.30	8.28	8.77	9.25	10.21	11.16	12.10	13.01	13.92	14.79	15.67
39	2.31	3.37	4.45	5.57	6.64	7.70	8.74	9.25	9.76	10.78	11.77	12.76	13.73	14.68	15.62	16.55
40	2.40	3.47	4.73	5.97	6.96	8.11	9.20	9.75	10.29	11.35	12.41	13.45	14.47	15.48	16.46	17.44
41	2.51	3.67	4.97	6.17	7.35	8.53	9.68	11.25	11.82	11.92	13.06	14.15	15.24	16.30	17.35	18.39
42	2.64	3.93	5.21	6.48	7.72	8.96	10.17	10.77	11.37	12.54	13.73	14.88	16.02	17.14	18.25	19.34
43	2.77	4.17	5.47	6.79	8.13	9.43	10.68	11.31	11.94	13.18	14.41	15.63	16.82	18.01	19.17	20.32
44	2.91	4.37	5.73	7.12	8.49	9.85	11.19	11.85	12.51	13.82	15.11	16.39	17.65	18.89	20.11	21.31
45	3.07	4.61	6.03	7.49	8.90	10.31	11.72	12.41	13.10	14.48	15.85	17.17	18.49	19.80	21.09	22.36
46	3.17	4.73	6.27	7.79	9.30	10.79	12.28	13.00	13.71	15.15	16.57	17.97	19.35	20.72	22.07	23.41
47	3.32	4.94	6.53	8.14	9.71	11.27	12.81	13.57	14.32	15.83	17.32	18.79	20.24	21.67	23.09	24.49
48	3.48	5.18	6.87	8.60	10.14	11.76	13.37	14.17	14.96	16.53	18.09	19.62	21.14	22.64	24.12	25.59
49	3.61	5.37	7.17	8.98	10.57	12.27	13.94	14.78	15.61	17.26	18.89	20.49	22.08	23.63	25.18	26.72
50	3.77	5.58	7.43	9.33	11.01	12.78	14.53	15.40	16.26	17.98	19.67	21.35	23.00	24.64	26.26	27.87
51	3.93	5.82	7.73	9.66	11.47	13.31	15.13	16.04	16.94	18.72	20.49	22.24	23.97	25.68	27.37	29.04
52	4.09	6.05	8.03	10.03	11.93	13.84	15.74	16.68	17.62	19.47	21.32	23.14	24.95	26.73	28.49	30.24
53	4.24	6.31	8.39	10.48	12.46	14.46	16.47	17.46	18.43	20.38	22.32	24.23	26.12	27.99	29.84	31.66
54	4.40	6.53	8.67	10.78	12.81	14.86	17.00	18.02	19.04	21.04	23.03	25.00	26.97	28.91	30.81	32.71
55	4.54	6.74	8.96	11.19	13.30	15.43	17.65	18.71	19.76	21.84	23.91	25.96	28.00	30.01	32.01	33.98
56	4.71	7.00	9.27	11.58	13.76	15.97	18.27	19.36	20.45	22.61	24.76	26.89	28.99	31.08	33.15	35.21
57	4.88	7.24	9.63	12.03	14.30	16.60	18.98	20.13	21.26	23.51	25.75	27.96	30.15	32.32	34.47	36.59
58	5.04	7.44	10.01	12.46	14.81	17.26	19.77	20.95	22.13	24.48	26.81	29.12	31.40	33.67	35.91	38.14
59	5.19	7.70	10.30	12.91	15.41	17.96	20.56	21.79	23.01	25.46	27.89	30.29	32.67	35.03	37.37	39.69
60	5.37	7.93	10.63	13.34	15.94	18.59	21.27	22.54	23.81	26.34	28.86	31.36	33.83	36.29	38.72	41.13

* Kips = 1,000 pounds

Table 42.--Log weights for scaling lengths of 34 to 60 feet: density index = 68 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LARGE END DIAMETER (INCHES)	34	36	38	40	42	44	46	48	50	52	54	56	58	60
6	.17	.17	.17	.17	.17	.17	.17	.17	.16	.16	.16	.16	.16	.11
7	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23	.23
8	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
9	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37	.37
10	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44
11	.51	.51	.51	.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51
12	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
13	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65
14	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72
15	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79
16	1.86	1.86	1.86	1.86	2.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86
17	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93
18	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
19	2.07	2.07	2.07	2.07	2.07	2.07	2.07	2.07	2.07	2.07	2.07	2.07	2.07	2.07
20	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14
21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21
22	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28
23	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35
24	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42
25	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49
26	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56
27	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63
28	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70
29	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
30	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84
31	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91
32	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98
33	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05
34	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12
35	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19
36	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26
37	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33
38	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40
39	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47
40	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54
41	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61
42	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68
43	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
44	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82
45	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89
46	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96
47	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03
48	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10
49	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17
50	4.24	4.24	4.24	4.24	4.24	4.24	4.24	4.24	4.24	4.24	4.24	4.24	4.24	4.24
51	4.31	4.31	4.31	4.31	4.31	4.31	4.31	4.31	4.31	4.31	4.31	4.31	4.31	4.31
52	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38
53	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
54	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52
55	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59
56	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66
57	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73
58	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80
59	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87
60	4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94

* 1KIP=1000 POUNDS

Table 43.--Log weights for scaling lengths of 4 to 32 feet: density index = 70 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KIPS*) FOR DENSITY INDEX=70

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	4	6	8	10	12	14	16	17	18	20	22	24	26	28	30	32
6	.16	.17	.09	.11	.13	.14	.15	.16	.17	.17	.18	.19	.19	.19	.20	.20
7	.17	.19	.13	.16	.18	.20	.22	.23	.24	.26	.27	.28	.29	.30	.30	.31
8	.19	.14	.17	.21	.24	.28	.30	.22	.33	.35	.37	.39	.41	.42	.43	.44
9	.17	.17	.22	.27	.32	.36	.40	.42	.43	.47	.49	.52	.55	.57	.59	.60
10	.15	.21	.28	.34	.41	.45	.50	.52	.55	.59	.63	.67	.71	.74	.76	.79
11	.18	.25	.34	.42	.49	.56	.62	.65	.68	.74	.79	.84	.88	.93	.97	1.00
12	.12	.32	.41	.50	.59	.67	.75	.79	.83	.90	.96	1.03	1.08	1.14	1.19	1.24
13	.15	.37	.49	.61	.72	.80	.89	.94	.99	1.07	1.15	1.23	1.30	1.37	1.44	1.50
14	.20	.43	.57	.71	.82	.94	1.05	1.11	1.16	1.26	1.36	1.45	1.54	1.63	1.71	1.79
15	.24	.50	.65	.80	.95	1.09	1.22	1.28	1.35	1.47	1.59	1.70	1.80	1.91	2.01	2.09
16	.29	.57	.75	.92	1.09	1.25	1.40	1.47	1.55	1.69	1.83	1.96	2.08	2.20	2.32	2.43
17	.44	.65	.85	1.04	1.23	1.42	1.59	1.67	1.76	1.92	2.09	2.24	2.38	2.53	2.66	2.79
18	.49	.73	.95	1.17	1.39	1.60	1.80	1.90	1.99	2.18	2.36	2.54	2.71	2.87	3.03	3.18
19	.55	.81	1.07	1.31	1.56	1.79	2.02	2.13	2.24	2.45	2.65	2.85	3.05	3.23	3.41	3.59
20	.61	.90	1.19	1.46	1.73	1.99	2.25	2.37	2.49	2.73	2.97	3.19	3.41	3.62	3.82	4.02
21	.67	.99	1.31	1.62	1.91	2.21	2.49	2.63	2.76	3.03	3.29	3.55	3.79	4.03	4.26	4.48
22	.74	1.09	1.44	1.78	2.11	2.43	2.74	2.89	3.05	3.35	3.64	3.92	4.19	4.46	4.72	4.97
23	.81	1.20	1.58	1.95	2.31	2.67	3.01	3.18	3.35	3.68	4.00	4.31	4.62	4.91	5.20	5.48
24	.88	1.31	1.72	2.13	2.52	2.91	3.29	3.48	3.66	4.03	4.38	4.72	5.06	5.38	5.70	6.01
25	.96	1.42	1.87	2.31	2.75	3.17	3.59	3.79	3.99	4.39	4.77	5.15	5.52	5.88	6.23	6.57
26	1.05	1.53	2.03	2.51	2.98	3.44	3.89	4.11	4.33	4.76	5.19	5.60	6.00	6.40	6.79	7.16
27	1.13	1.66	2.19	2.71	3.22	3.72	4.21	4.45	4.68	5.16	5.62	6.07	6.51	6.94	7.36	7.77
28	1.24	1.79	2.36	2.92	3.47	4.01	4.54	4.80	5.05	5.56	6.06	6.55	7.03	7.50	7.96	8.40
29	1.34	1.93	2.53	3.14	3.73	4.31	4.88	5.16	5.44	5.98	6.53	7.06	7.58	8.08	8.58	9.06
30	1.38	2.09	2.71	3.36	4.00	4.62	5.24	5.54	5.84	6.43	7.01	7.58	8.14	8.69	9.22	9.75
31	1.47	2.19	2.90	3.59	4.26	4.95	5.60	5.93	6.25	6.89	7.51	8.12	8.72	9.31	9.89	10.46
32	1.57	2.34	3.09	3.83	4.56	5.28	5.98	6.33	6.68	7.36	8.03	8.68	9.33	9.96	10.58	11.19
33	1.67	2.49	3.29	4.08	4.86	5.62	6.38	75	7.12	7.84	8.56	9.25	9.95	10.63	11.30	11.95
34	1.78	2.64	3.50	4.34	5.17	5.98	6.78	.18	7.57	8.35	9.11	9.86	10.61	11.32	12.04	12.74
35	1.88	2.80	3.71	4.60	5.48	6.35	7.20	7.62	8.04	8.87	9.68	10.48	11.28	12.04	12.81	13.55
36	1.98	2.97	3.93	4.87	5.81	6.72	7.63	8.08	8.52	9.40	10.26	11.11	11.96	12.77	13.58	14.38
37	2.11	3.14	4.15	5.15	6.14	7.11	8.07	8.55	9.02	9.95	10.86	11.77	12.66	13.53	14.39	15.24
38	2.22	3.31	4.38	5.44	6.48	7.51	8.53	9.03	9.53	10.51	11.48	12.44	13.39	14.31	15.23	16.13
39	2.34	3.48	4.60	5.74	6.84	7.92	8.99	9.52	10.05	11.09	12.12	13.13	14.13	15.11	16.08	17.04
40	2.46	3.67	4.86	6.04	7.20	8.34	9.47	10.03	10.59	11.69	12.77	13.84	14.90	15.94	16.96	17.97
41	2.59	3.86	5.11	6.35	7.57	8.78	9.97	10.56	11.14	12.30	13.44	14.57	15.68	16.78	17.86	18.93
42	2.71	4.04	5.37	6.67	7.95	9.22	10.47	11.09	11.71	12.93	14.13	15.32	16.49	17.65	18.79	19.91
43	2.85	4.24	5.63	6.99	8.34	9.67	11.00	11.64	12.29	13.57	14.84	16.09	17.32	18.54	19.74	20.92
44	2.98	4.45	5.91	7.33	8.74	10.14	11.52	12.20	12.88	14.23	15.56	16.87	18.17	19.45	20.71	21.96
45	3.12	4.66	6.17	7.67	9.15	10.61	12.06	12.78	13.49	14.91	16.32	17.67	19.04	20.38	21.71	23.02
46	3.26	4.87	6.46	8.02	9.57	11.10	12.62	13.37	14.11	15.59	17.05	18.51	19.92	21.32	22.72	24.10
47	3.41	5.09	6.76	8.39	10.01	11.60	13.19	13.97	14.75	16.29	17.82	19.34	20.83	22.31	23.77	25.21
48	3.56	5.32	7.07	8.74	10.43	12.11	13.76	14.58	15.41	17.02	18.62	20.20	21.76	23.31	24.83	26.34
49	3.71	5.53	7.37	9.12	10.88	12.62	14.36	15.21	16.06	17.75	19.42	21.08	22.71	24.33	25.92	27.50
50	3.86	5.76	7.66	9.50	11.34	13.16	14.96	15.85	16.74	19.51	20.25	21.97	23.68	25.37	27.04	28.69
51	4.01	5.98	7.96	9.86	11.77	13.70	15.59	16.51	17.47	19.27	21.08	22.89	24.67	26.43	28.17	29.89
52	4.17	6.21	8.27	10.24	12.22	14.25	16.21	17.18	18.14	20.06	21.95	23.83	25.68	27.52	29.33	31.13
53	4.34	6.47	8.60	10.64	12.70	14.81	16.85	17.86	18.86	20.85	22.83	24.78	26.71	28.63	30.51	32.38
54	4.51	6.73	8.95	11.07	13.21	15.38	17.50	18.55	19.61	21.67	23.72	25.75	27.78	29.75	31.72	33.67
55	4.67	6.98	9.28	11.52	13.76	16.03	18.17	19.26	20.34	22.49	24.63	26.74	28.83	30.91	32.95	34.98
56	4.84	7.23	9.62	11.95	14.27	16.57	18.85	19.98	21.11	23.34	25.56	27.75	29.92	32.07	34.21	36.31
57	5.01	7.50	9.96	12.36	14.76	17.13	19.54	20.70	21.88	24.20	26.51	28.79	31.04	33.27	35.48	37.67
58	5.18	7.76	10.31	12.80	15.32	17.79	20.25	21.46	22.67	25.08	27.47	29.83	32.17	34.49	36.79	39.06
59	5.35	8.03	10.67	13.25	15.86	18.42	21.06	22.32	23.60	25.97	28.44	30.90	33.32	35.72	38.11	40.46
60	5.52	8.31	11.03	13.71	16.41	19.06	21.69	24.00	24.32	26.86	29.44	31.98	34.48	36.96	39.42	41.86

* 1KIP=1,000 POUNDS

Table 44.--Log weights for scaling lengths of 34 to 60 feet: density index = 70 pounds per cubic foot

[Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet]

LOG WEIGHT (KIPS*) FOR DENSITY INDEX=70

LARGE END DIAMETER (INCHES)	SCALING LENGTH (FEET)															
	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64
6	.19	.19	.19	.19	.19	.19	.19	.17	.17	.17	.17	.15	.14	.13	.11	.11
7	.31	.32	.32	.31	.31	.31	.31	.30	.30	.29	.29	.27	.27	.26	.25	.24
8	.45	.45	.46	.46	.46	.46	.46	.47	.47	.47	.47	.45	.44	.44	.43	.41
9	.62	.63	.63	.64	.65	.65	.66	.66	.66	.67	.67	.66	.65	.64	.64	.63
10	.81	.82	.83	.85	.85	.86	.87	.89	.89	.90	.91	.91	.90	.91	.91	.89
11	1.03	1.06	1.08	1.10	1.11	1.13	1.14	1.16	1.16	1.17	1.18	1.19	1.19	1.20	1.20	1.20
12	1.28	1.31	1.32	1.34	1.36	1.38	1.40	1.42	1.44	1.45	1.47	1.48	1.49	1.51	1.52	1.52
13	1.56	1.59	1.61	1.63	1.65	1.67	1.70	1.72	1.74	1.76	1.78	1.80	1.81	1.83	1.84	1.85
14	1.87	1.90	1.93	1.96	1.98	2.01	2.03	2.06	2.08	2.11	2.13	2.15	2.17	2.19	2.21	2.22
15	2.21	2.25	2.28	2.31	2.34	2.37	2.40	2.43	2.46	2.49	2.52	2.54	2.56	2.58	2.60	2.62
16	2.57	2.61	2.65	2.69	2.72	2.76	2.80	2.83	2.87	2.90	2.93	2.96	2.99	3.01	3.03	3.05
17	2.96	3.00	3.05	3.09	3.13	3.17	3.21	3.25	3.29	3.33	3.36	3.40	3.43	3.46	3.48	3.50
18	3.38	3.43	3.48	3.53	3.57	3.62	3.66	3.71	3.75	3.79	3.83	3.87	3.90	3.94	3.96	3.98
19	3.82	3.87	3.93	3.98	4.03	4.08	4.13	4.18	4.23	4.27	4.32	4.36	4.40	4.43	4.46	4.48
20	4.31	4.37	4.43	4.49	4.54	4.60	4.65	4.71	4.76	4.81	4.86	4.90	4.94	4.98	5.01	5.03
21	4.84	4.91	4.98	5.04	5.11	5.17	5.23	5.29	5.34	5.40	5.45	5.50	5.54	5.58	5.62	5.65
22	5.41	5.48	5.56	5.63	5.70	5.77	5.83	5.90	5.96	6.02	6.08	6.13	6.18	6.23	6.27	6.31
23	5.99	6.08	6.16	6.24	6.32	6.39	6.46	6.53	6.60	6.67	6.73	6.79	6.84	6.89	6.94	6.98
24	6.62	6.71	6.81	6.90	6.98	7.06	7.14	7.22	7.29	7.36	7.43	7.49	7.55	7.61	7.66	7.70
25	7.31	7.41	7.51	7.61	7.70	7.79	7.88	7.96	8.04	8.12	8.19	8.26	8.33	8.39	8.44	8.49
26	8.03	8.14	8.25	8.36	8.46	8.56	8.65	8.74	8.83	8.92	9.00	9.08	9.15	9.22	9.28	9.33
27	8.80	8.92	9.04	9.16	9.27	9.38	9.48	9.58	9.68	9.77	9.86	9.94	10.02	10.09	10.16	10.22
28	9.64	9.77	9.90	10.03	10.15	10.26	10.38	10.49	10.59	10.70	10.79	10.89	10.97	11.05	11.13	11.20
29	10.54	10.68	10.83	10.96	11.09	11.22	11.34	11.46	11.57	11.68	11.79	11.89	11.98	12.07	12.15	12.23
30	11.48	11.63	11.77	11.92	12.06	12.20	12.33	12.45	12.57	12.69	12.80	12.91	13.01	13.10	13.19	13.27
31	12.41	12.57	12.73	12.88	13.03	13.17	13.30	13.44	13.57	13.69	13.81	13.93	14.03	14.13	14.23	14.31
32	13.38	13.55	13.72	13.88	14.03	14.18	14.32	14.46	14.59	14.72	14.85	14.97	15.08	15.18	15.28	15.37
33	14.36	14.54	14.72	14.89	15.05	15.21	15.36	15.50	15.64	15.78	15.91	16.03	16.15	16.26	16.36	16.46
34	15.43	15.62	15.81	15.99	16.16	16.33	16.48	16.64	16.78	16.93	17.06	17.20	17.32	17.44	17.55	17.65
35	16.54	16.74	16.94	17.13	17.32	17.49	17.66	17.82	17.98	18.13	18.27	18.41	18.54	18.66	18.78	18.89
36	17.67	17.89	18.10	18.30	18.50	18.68	18.86	19.03	19.20	19.36	19.51	19.66	19.80	19.93	20.05	20.17
37	18.84	19.07	19.29	19.51	19.71	19.91	20.10	20.28	20.46	20.63	20.79	20.95	21.10	21.24	21.37	21.50
38	20.04	20.28	20.52	20.75	20.97	21.18	21.38	21.58	21.77	21.95	22.12	22.29	22.45	22.60	22.74	22.87
39	21.28	21.54	21.79	22.03	22.27	22.49	22.71	22.92	23.12	23.32	23.51	23.69	23.86	24.02	24.17	24.31
40	22.56	22.83	23.09	23.35	23.60	23.84	24.07	24.29	24.51	24.72	24.92	25.11	25.29	25.46	25.62	25.77
41	23.88	24.17	24.44	24.71	24.97	25.23	25.47	25.71	25.94	26.16	26.38	26.58	26.78	26.96	27.13	27.29
42	25.24	25.55	25.84	26.13	26.41	26.68	26.94	27.20	27.45	27.69	27.93	28.15	28.37	28.57	28.76	28.93
43	26.65	26.97	27.28	27.59	27.89	28.18	28.46	28.73	29.00	29.26	29.51	29.75	29.98	30.20	30.40	30.59
44	28.10	28.45	28.78	29.11	29.43	29.74	30.04	30.33	30.62	30.89	31.16	31.41	31.66	31.89	32.11	32.31
45	29.61	29.98	30.34	30.69	31.03	31.36	31.68	31.99	32.29	32.58	32.86	33.13	33.39	33.64	33.87	34.09
46	31.17	31.57	31.95	32.32	32.68	33.03	33.37	33.70	34.02	34.33	34.63	34.92	35.20	35.46	35.71	35.94
47	32.79	33.21	33.61	34.00	34.38	34.75	35.11	35.46	35.80	36.13	36.45	36.76	37.06	37.34	37.61	37.86
48	34.46	34.90	35.33	35.75	36.15	36.54	36.92	37.29	37.65	38.00	38.34	38.67	38.98	39.28	39.56	39.83
49	36.18	36.65	37.11	37.56	37.99	38.41	38.82	39.22	39.60	39.97	40.33	40.68	41.01	41.33	41.62	41.90
50	37.96	38.46	38.94	39.41	39.87	40.32	40.76	41.18	41.59	41.99	42.38	42.75	43.11	43.45	43.77	44.07
51	39.80	40.32	40.84	41.34	41.83	42.31	42.77	43.22	43.66	44.08	44.49	44.88	45.25	45.61	45.94	46.25
52	41.70	42.26	42.80	43.33	43.85	44.35	44.84	45.31	45.77	46.22	46.65	47.06	47.46	47.83	48.19	48.52
53	43.66	44.25	44.82	45.38	45.93	46.46	46.98	47.48	47.97	48.44	48.90	49.33	49.75	50.14	50.51	50.86
54	45.69	46.30	46.91	47.50	48.07	48.63	49.17	49.70	50.21	50.71	51.19	51.65	52.09	52.50	52.90	53.27
55	47.78	48.43	49.07	49.69	50.30	50.89	51.46	52.01	52.54	53.06	53.56	54.04	54.50	54.94	55.35	55.74
56	49.94	50.63	51.30	51.96	52.60	53.23	53.83	54.41	54.97	55.51	56.03	56.53	57.00	57.45	57.88	58.28
57	52.17	52.90	53.61	54.31	54.98	55.63	56.26	56.87	57.45	58.01	58.55	59.06	59.55	60.02	60.46	60.88
58	54.48	55.24	55.98	56.70	57.40	58.08	58.73	59.36	59.97	60.55	61.11	61.64	62.15	62.63	63.09	63.52
59	56.86	57.66	58.43	59.18	59.91	60.61	61.29	61.94	62.57	63.17	63.75	64.30	64.82	65.32	65.79	66.24
60	59.32	60.15	60.95	61.74	62.50	63.24	63.95	64.64	65.30	65.94	66.55	67.14	67.70	68.23	68.73	69.21

* 1KIP=1000 POUNDS

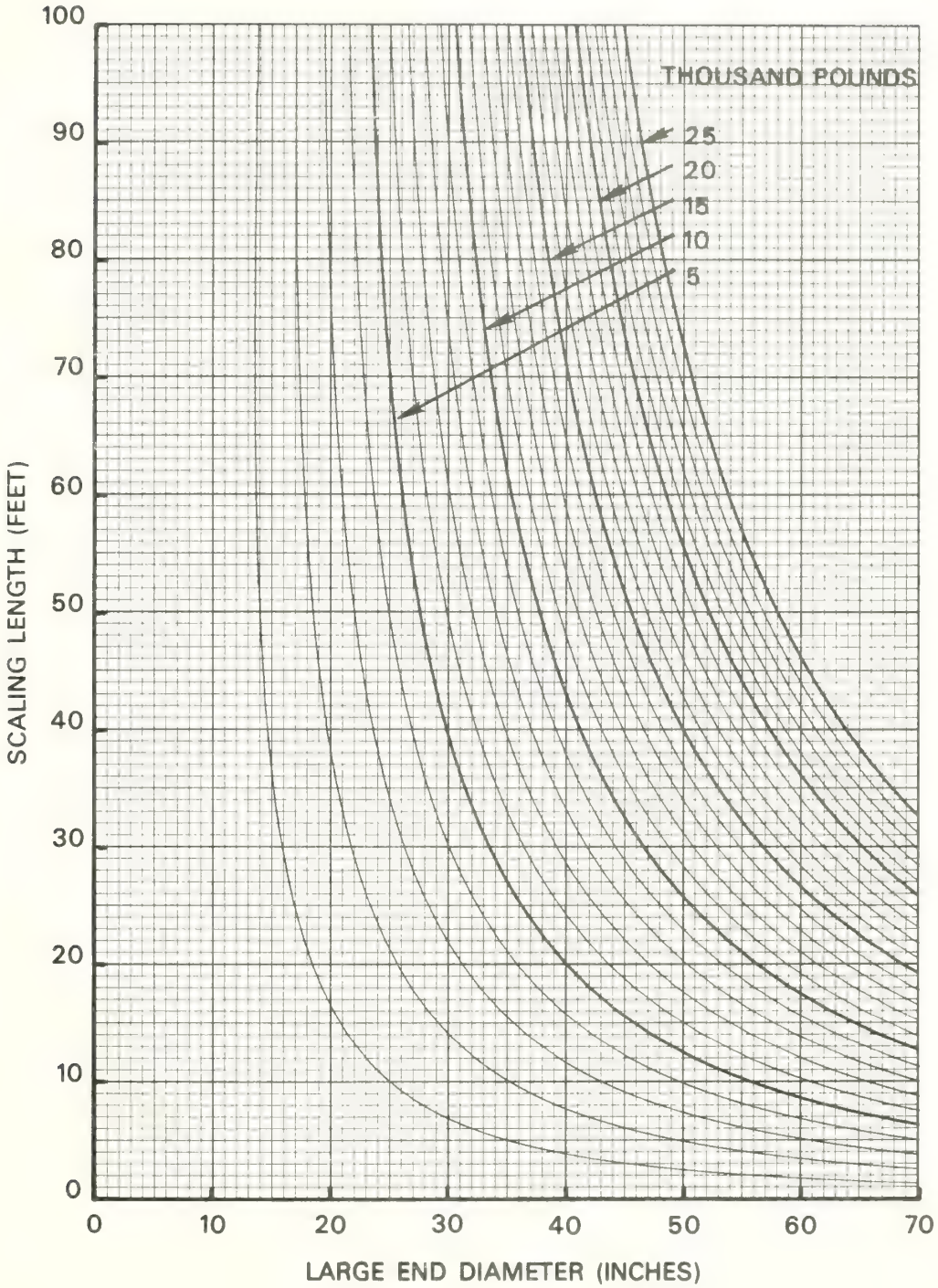


Figure 5.—Scaling length versus large end diameter for various log weights. Density index = 30 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

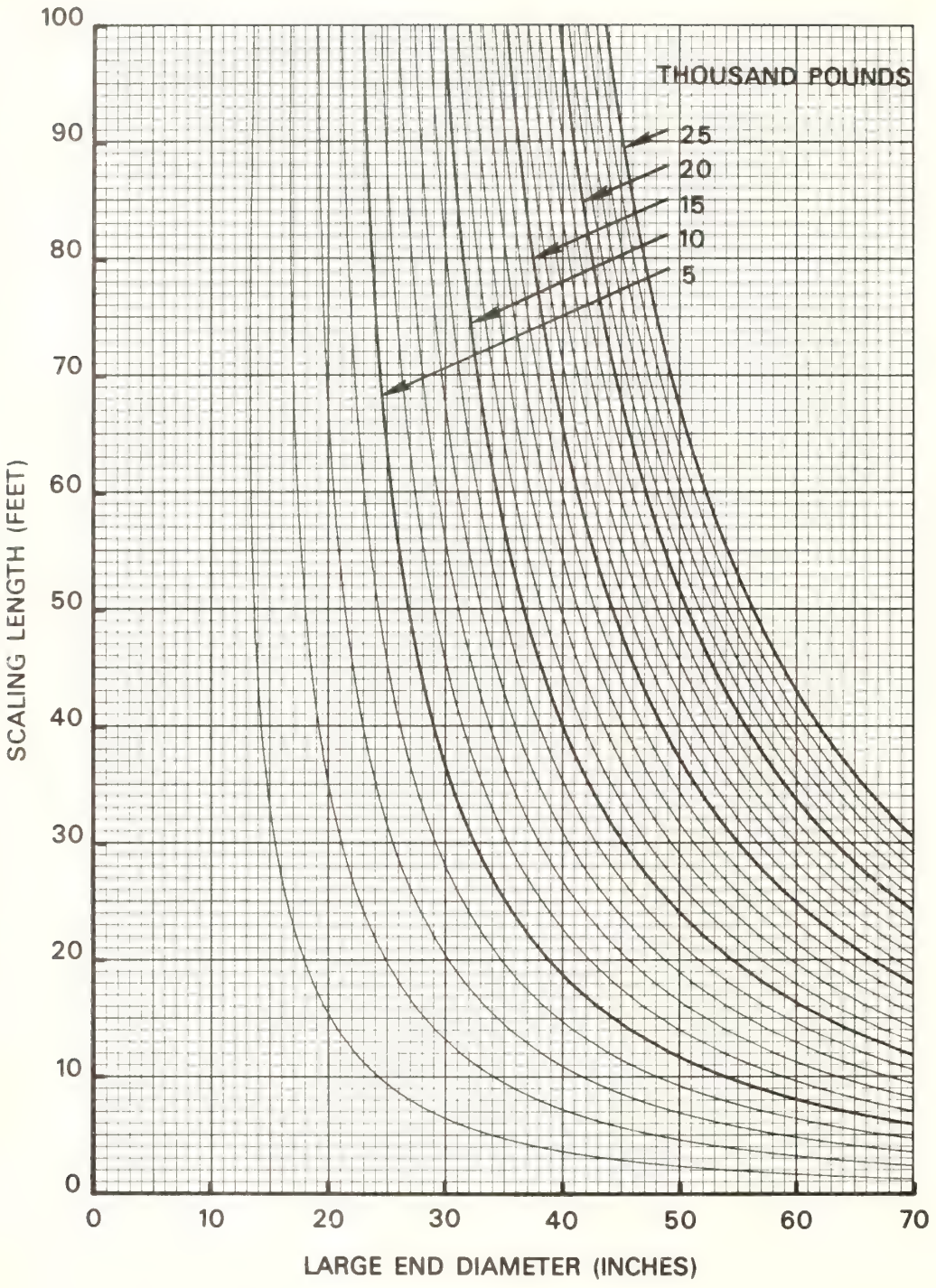


Figure 6.—Scaling length versus large end diameter for various log weights. Density index = 32 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

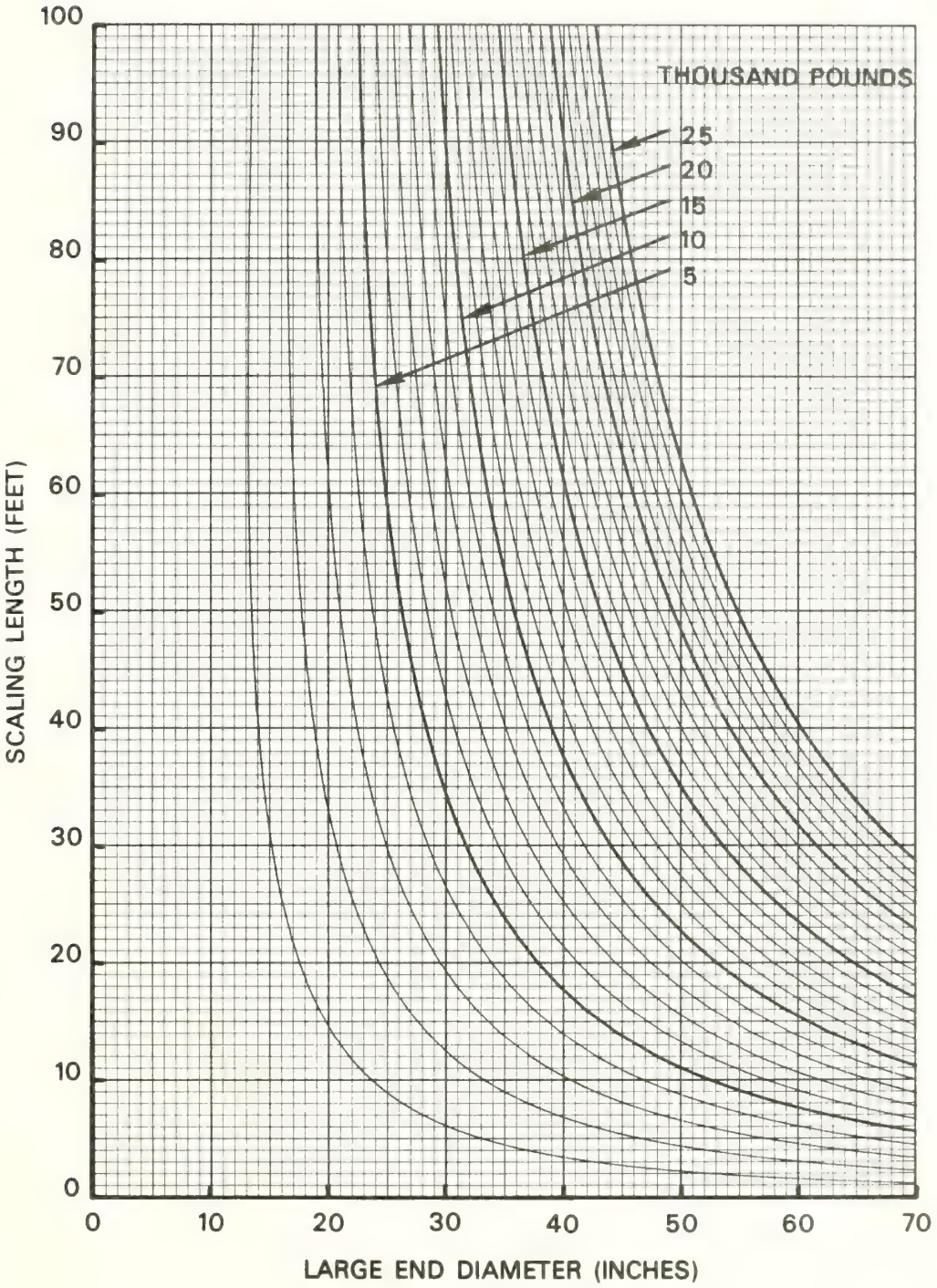


Figure 7.—Scaling length versus large end diameter for various log weights. Density index = 34 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

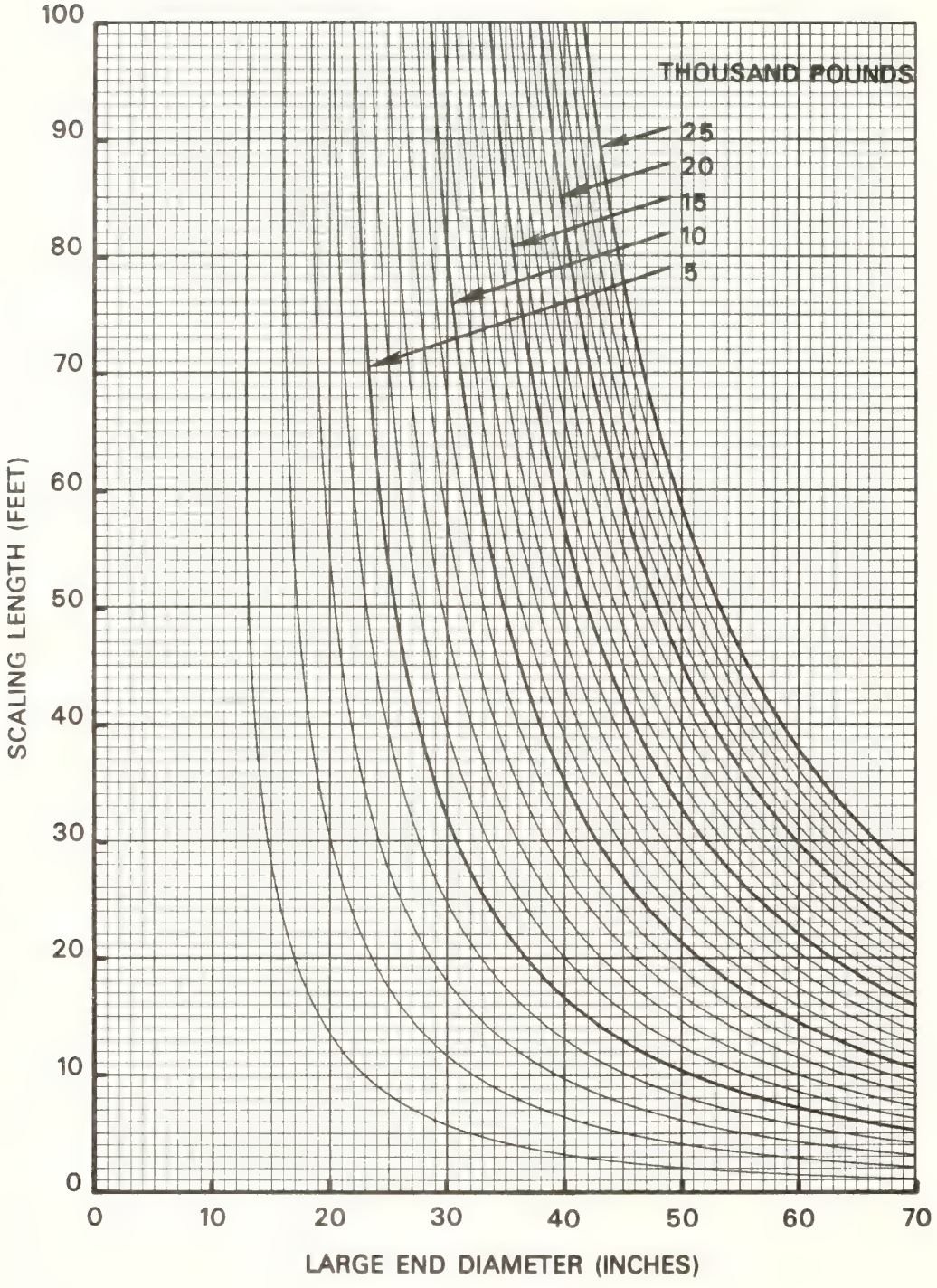


Figure 8.—Scaling length versus large end diameter for various log weights. Density index = 36 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

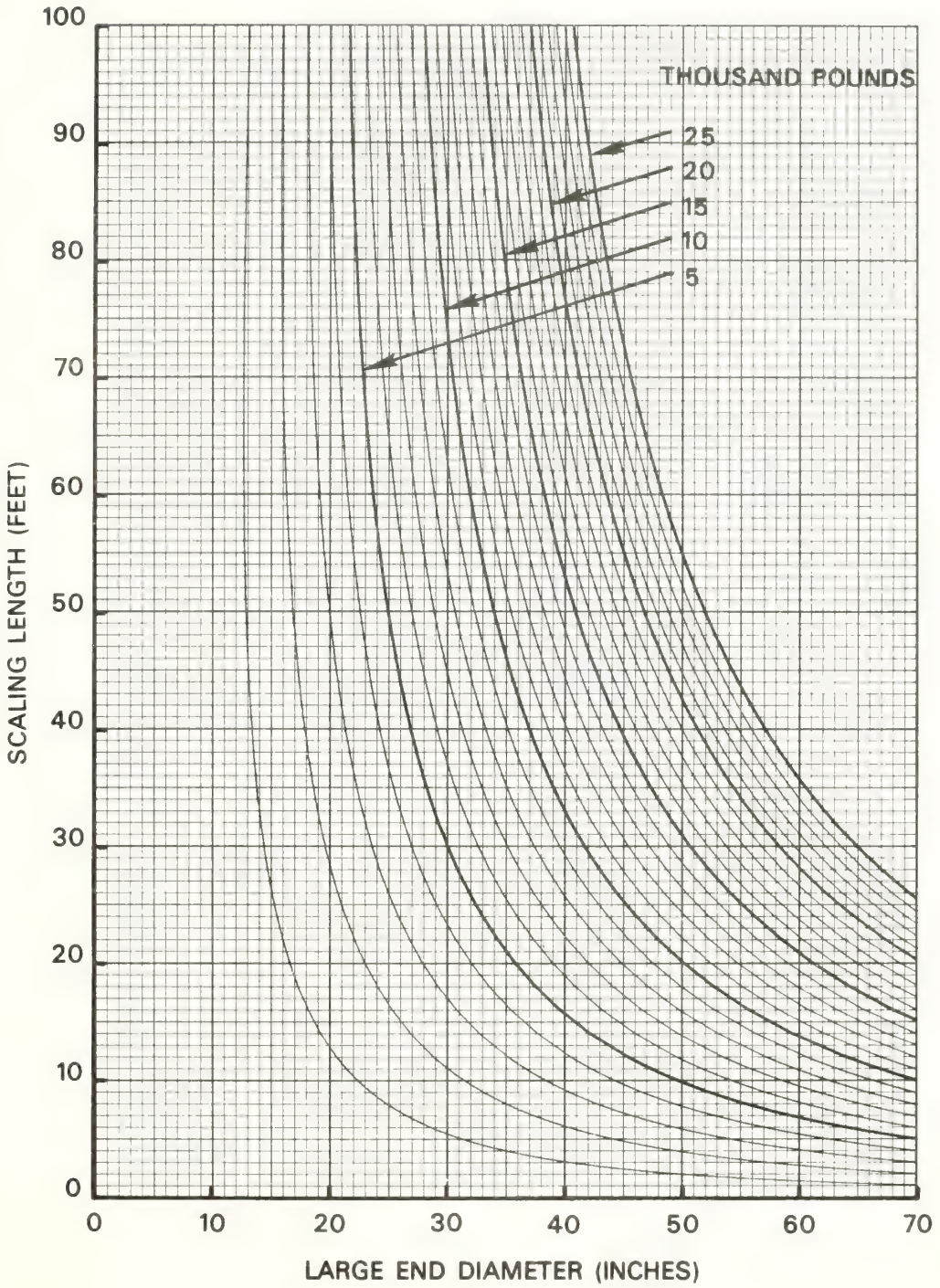


Figure 9.—Scaling length versus large end diameter for various log weights. Density index = 38 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

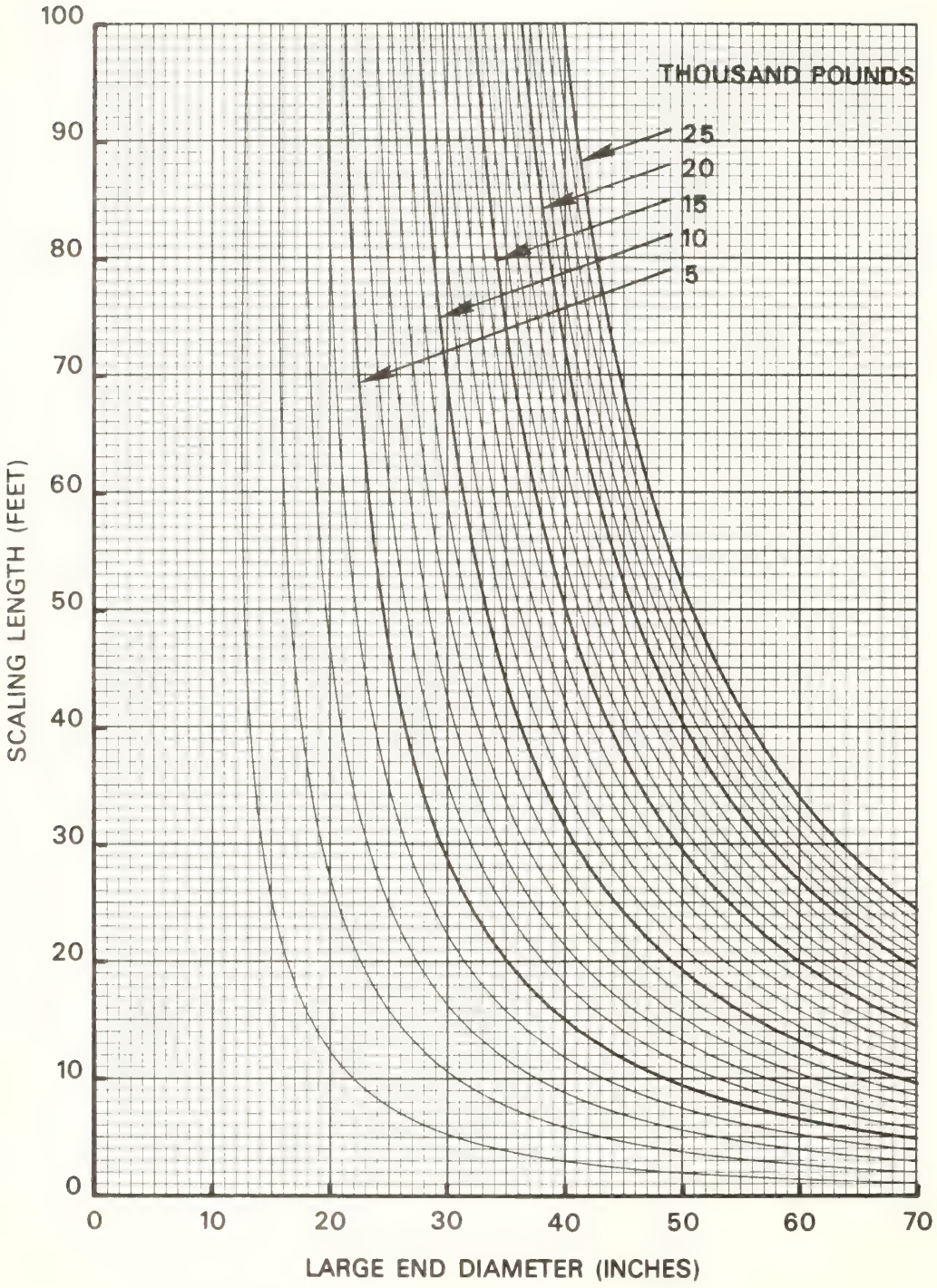


Figure 10.—Scaling length versus large end diameter for various log weights. Density index = 40 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

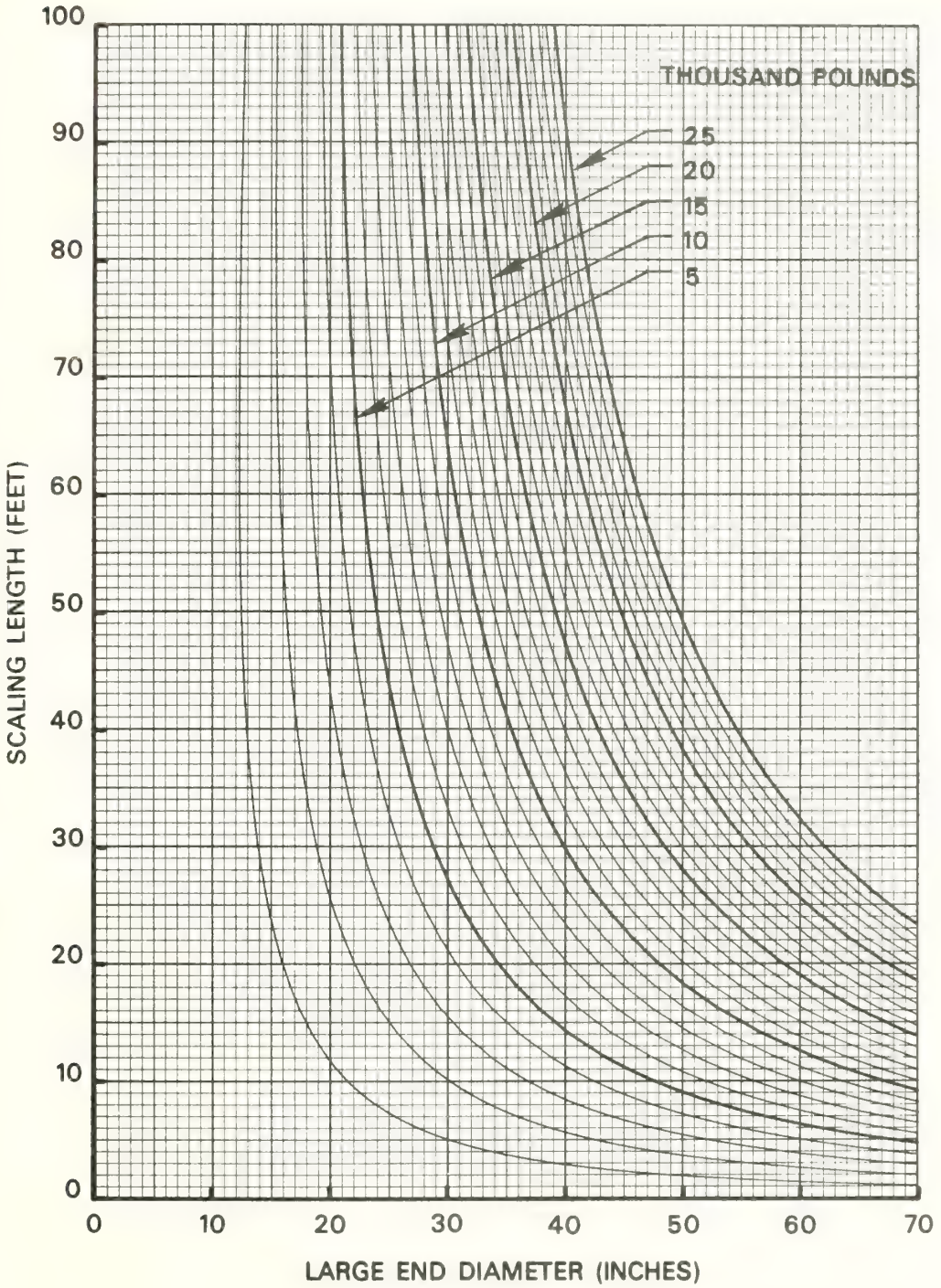


Figure 11.—Scaling length versus large end diameter for various log weights. Density index = 42 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

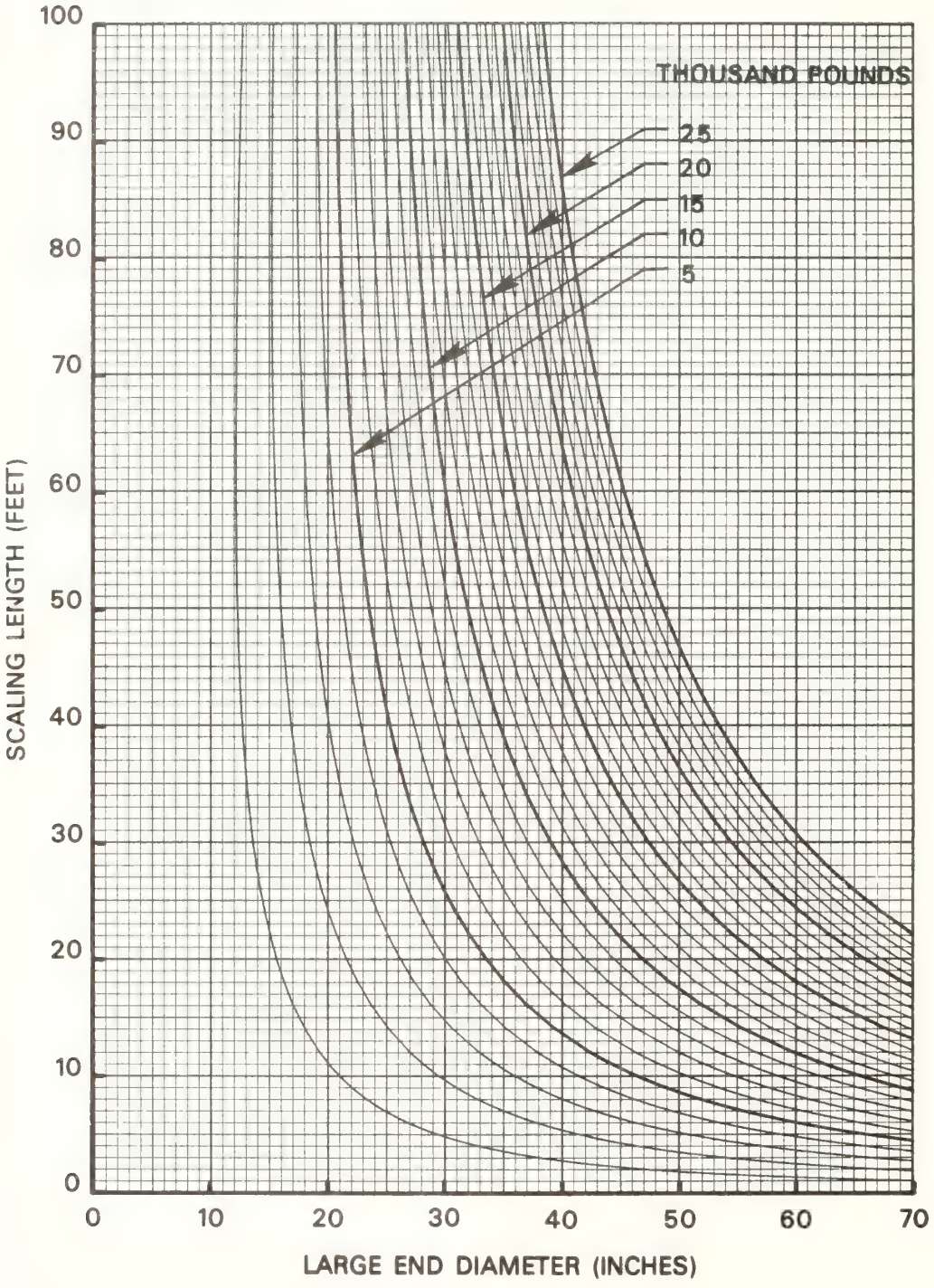


Figure 12.—Scaling length versus large end diameter for various log weights. Density index = 44 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

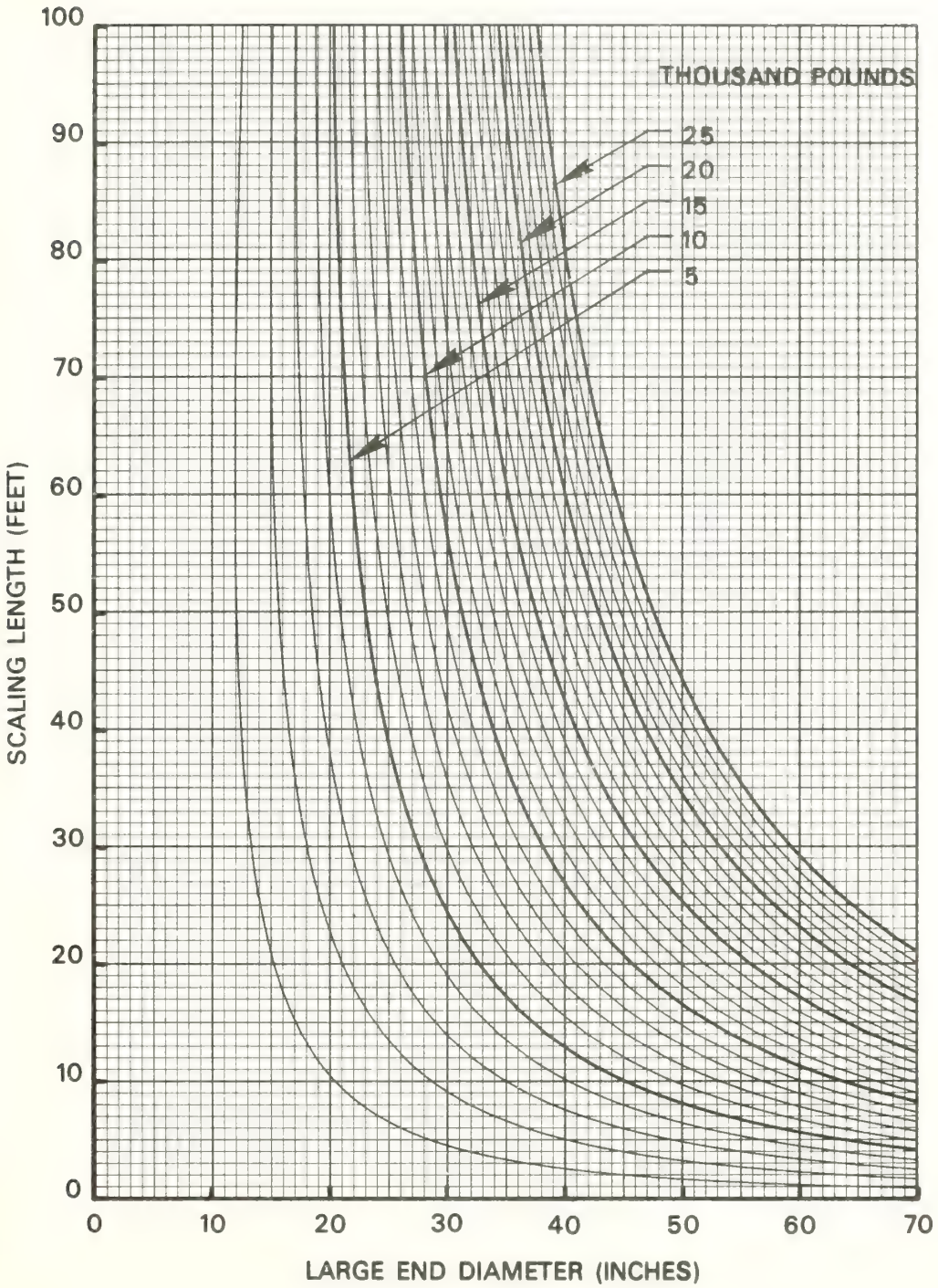


Figure 13.–Scaling length versus large end diameter for various log weights. Density index = 46 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

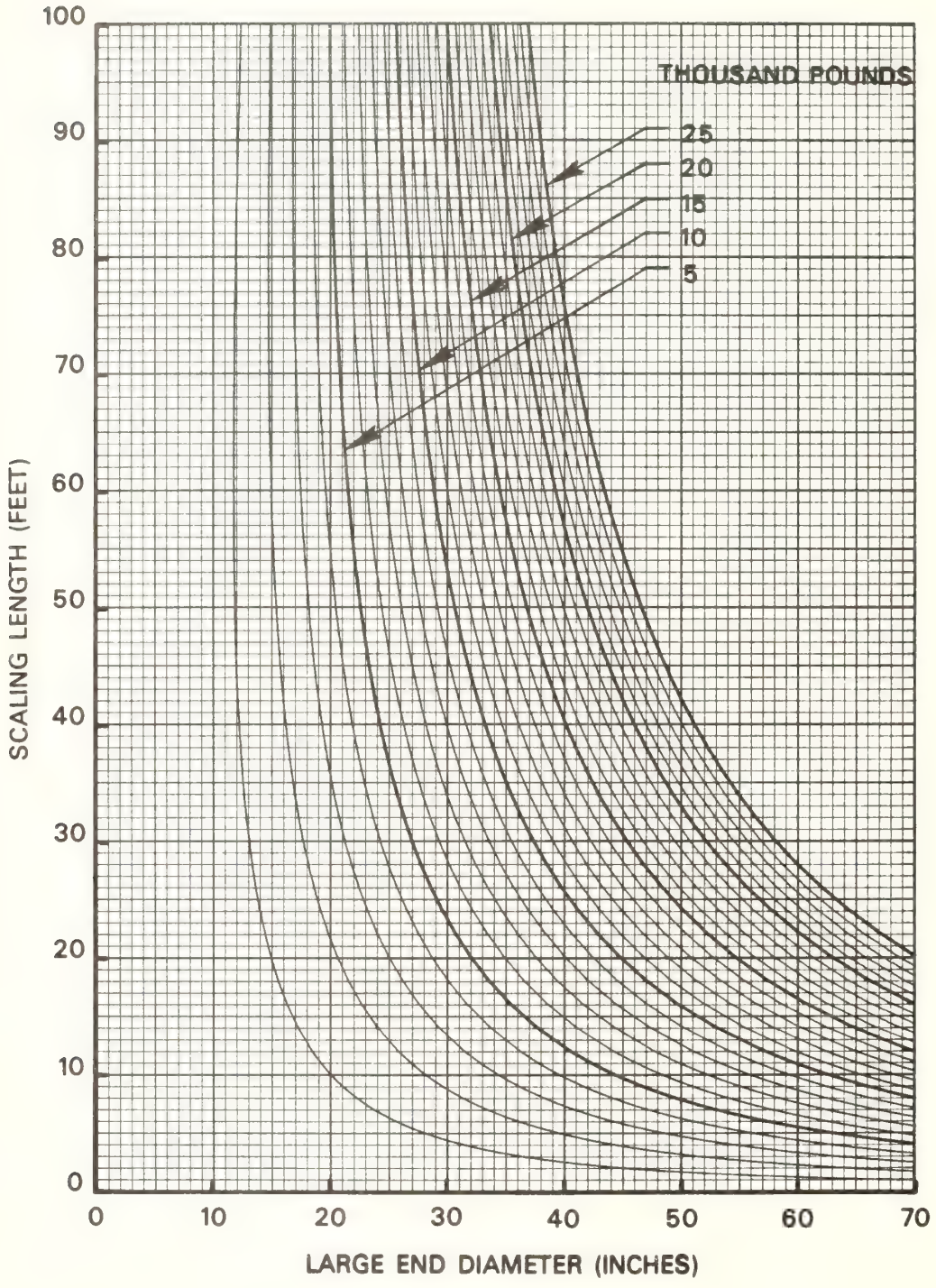


Figure 14.—Scaling length versus large end diameter for various log weights. Density index = 48 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

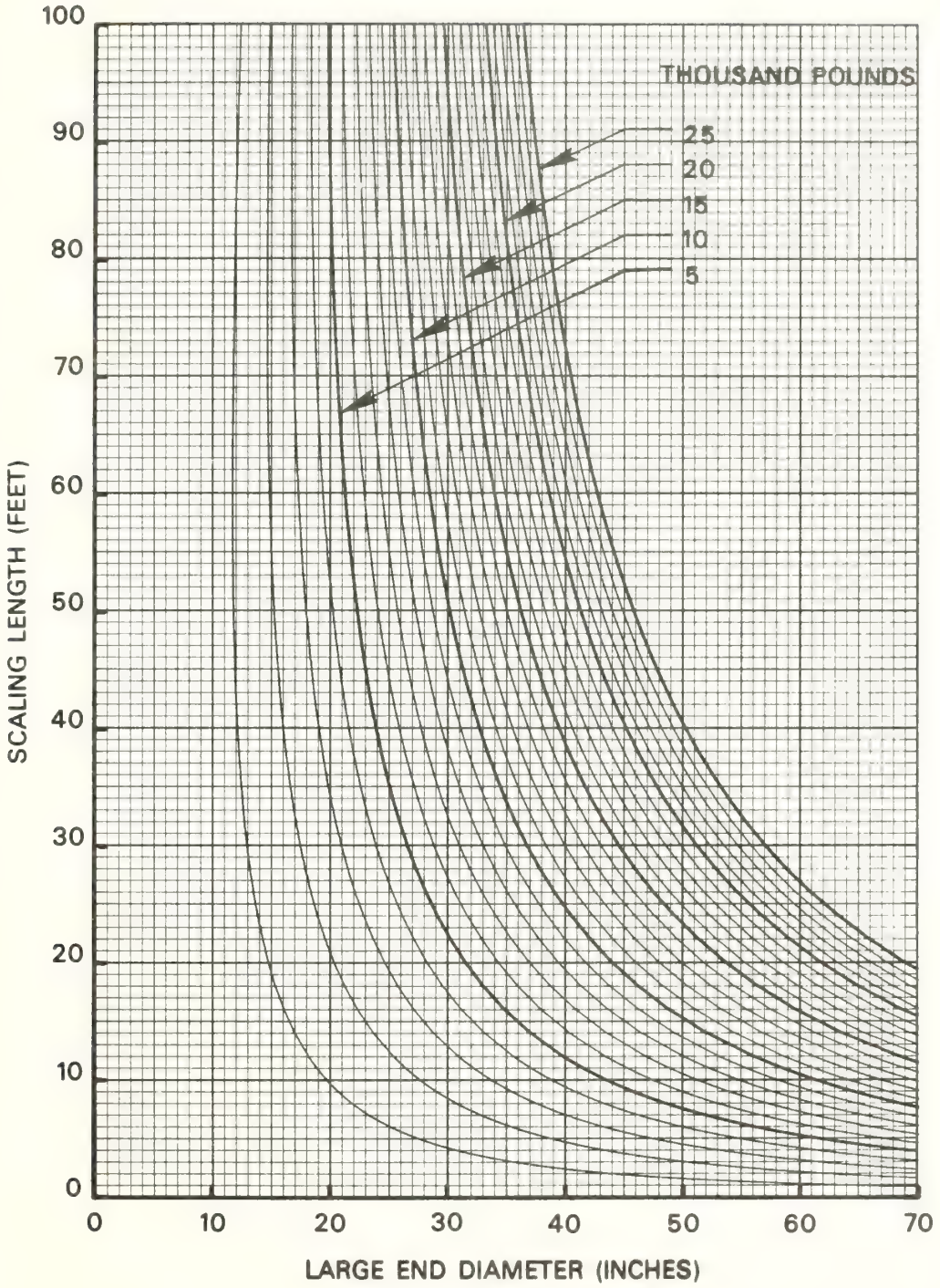


Figure 15.—Scaling length versus large end diameter for various log weights. Density index = 50 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

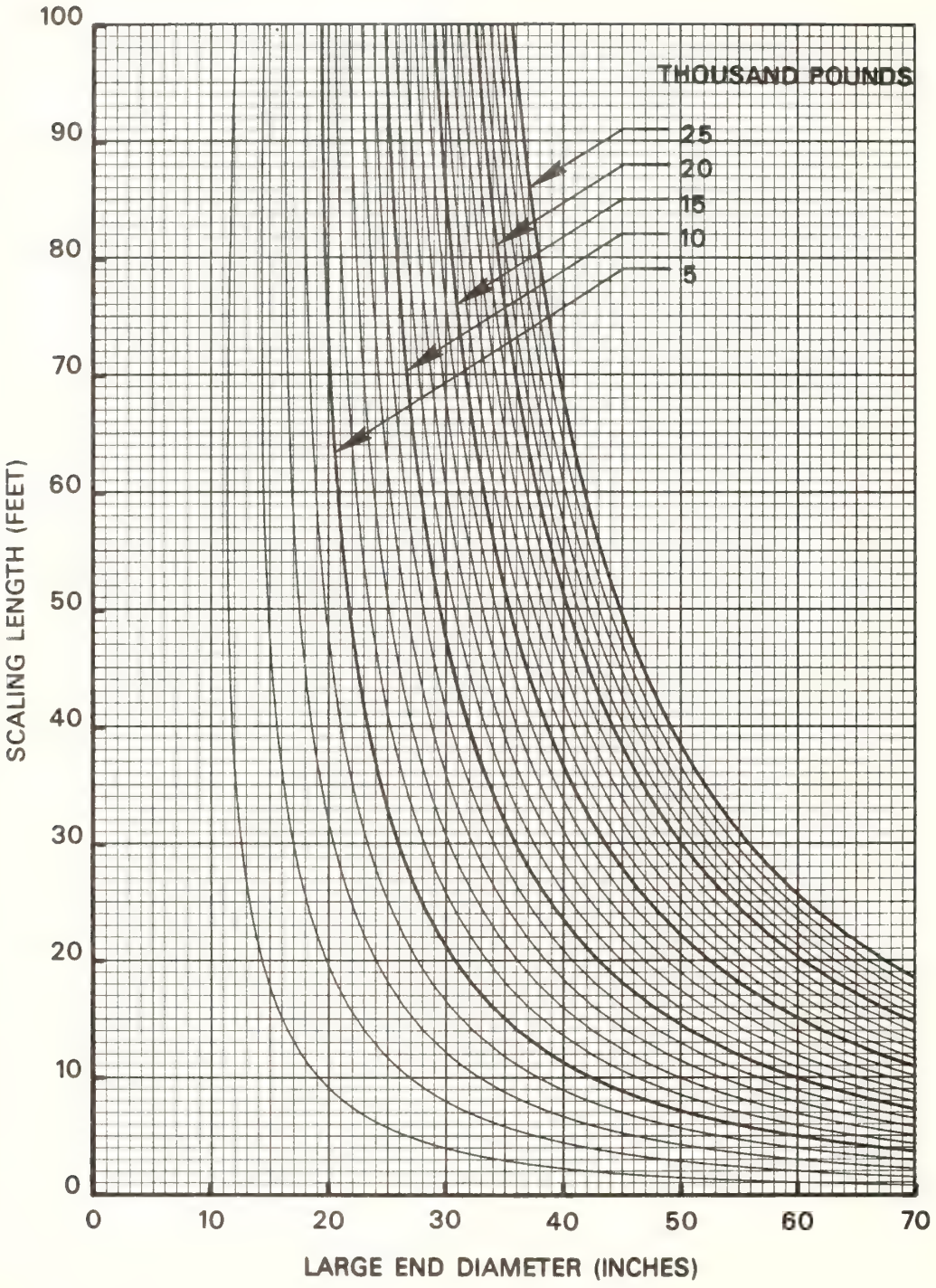


Figure 16.—Scaling length versus large end diameter for various log weights Density index = 52 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

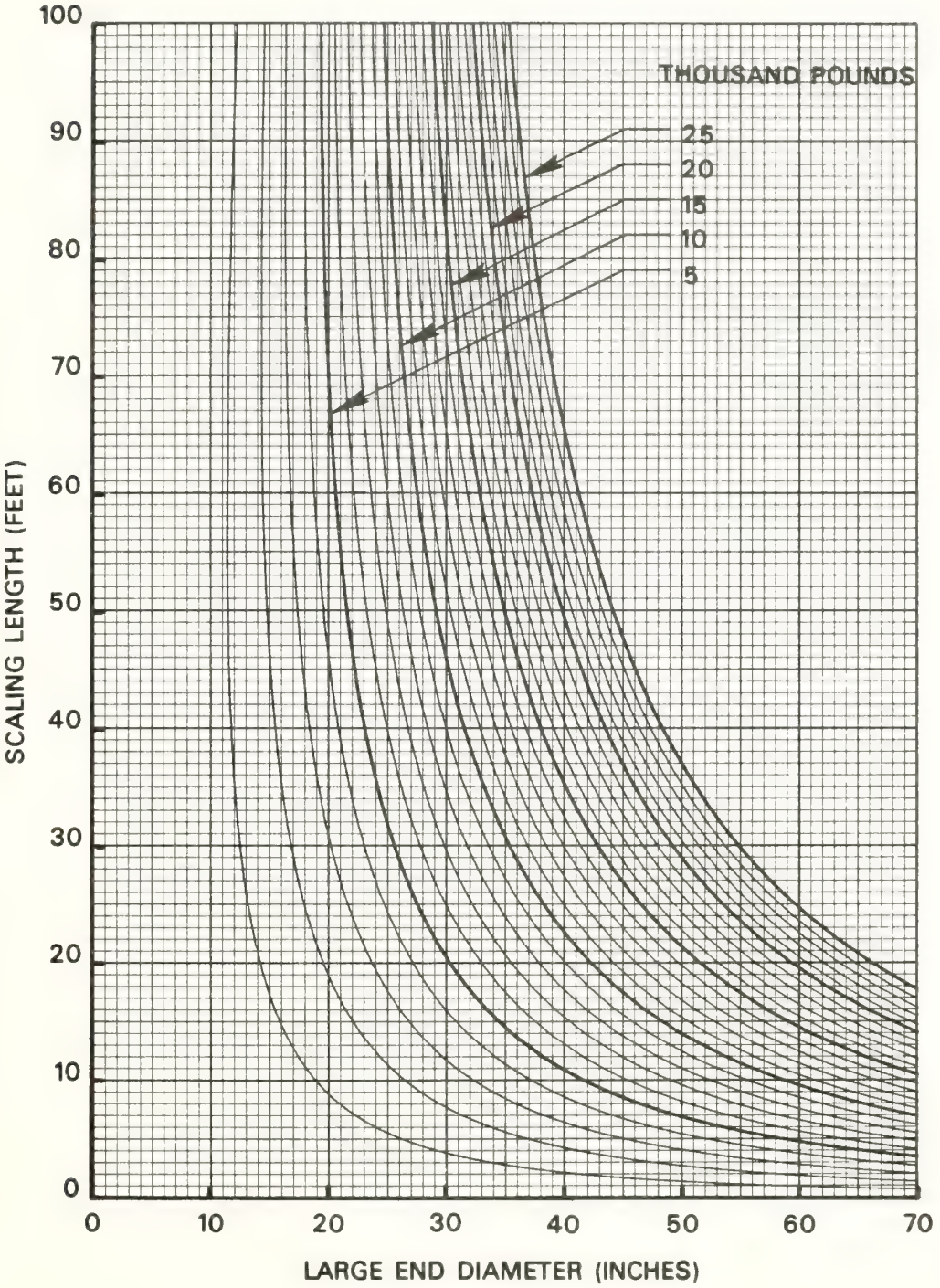


Figure 17.—Scaling length versus large end diameter for various log weights. Density index = 54 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

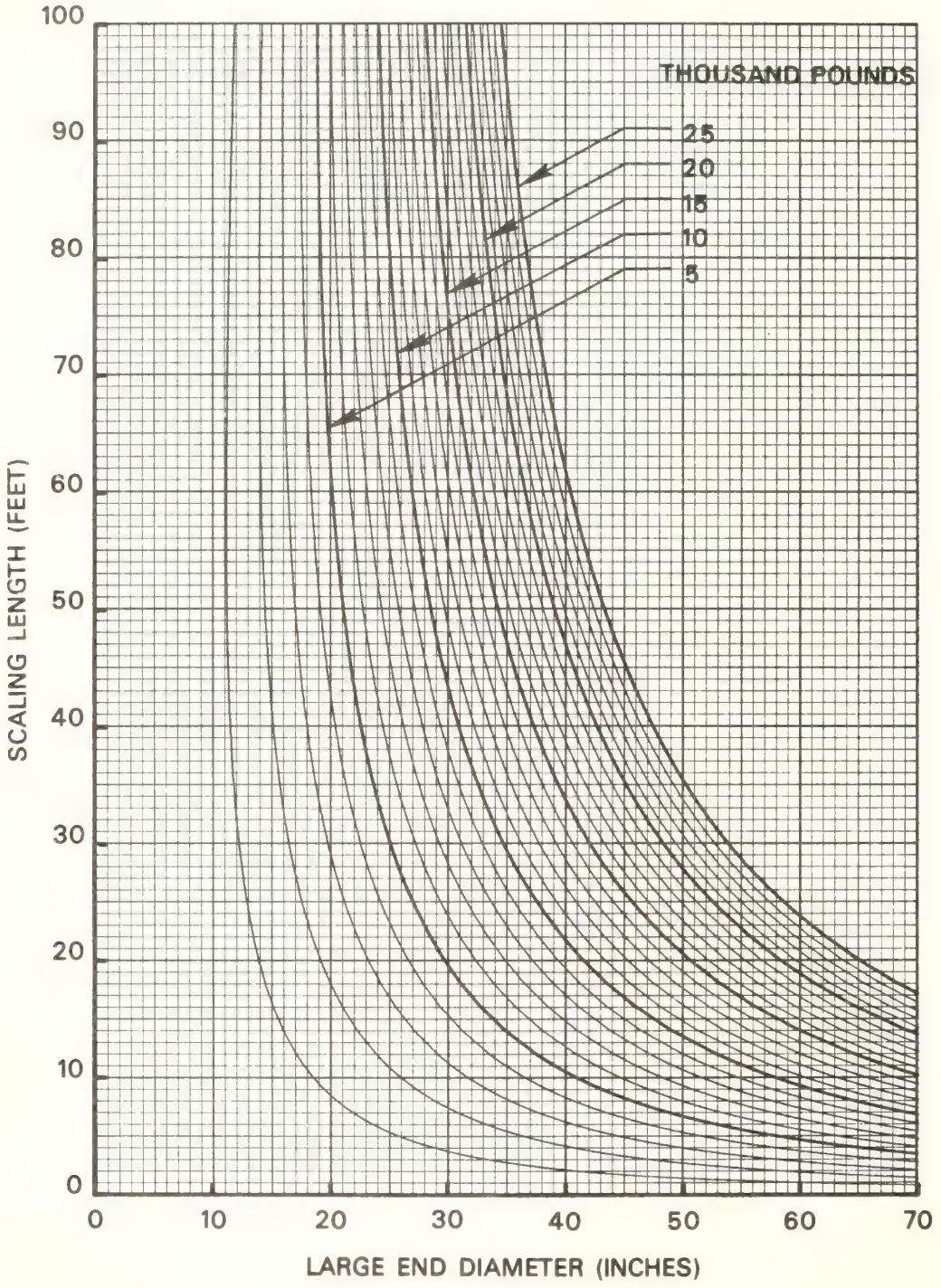


Figure 18.—Scaling length versus large end diameter for various log weights. Density index = 56 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

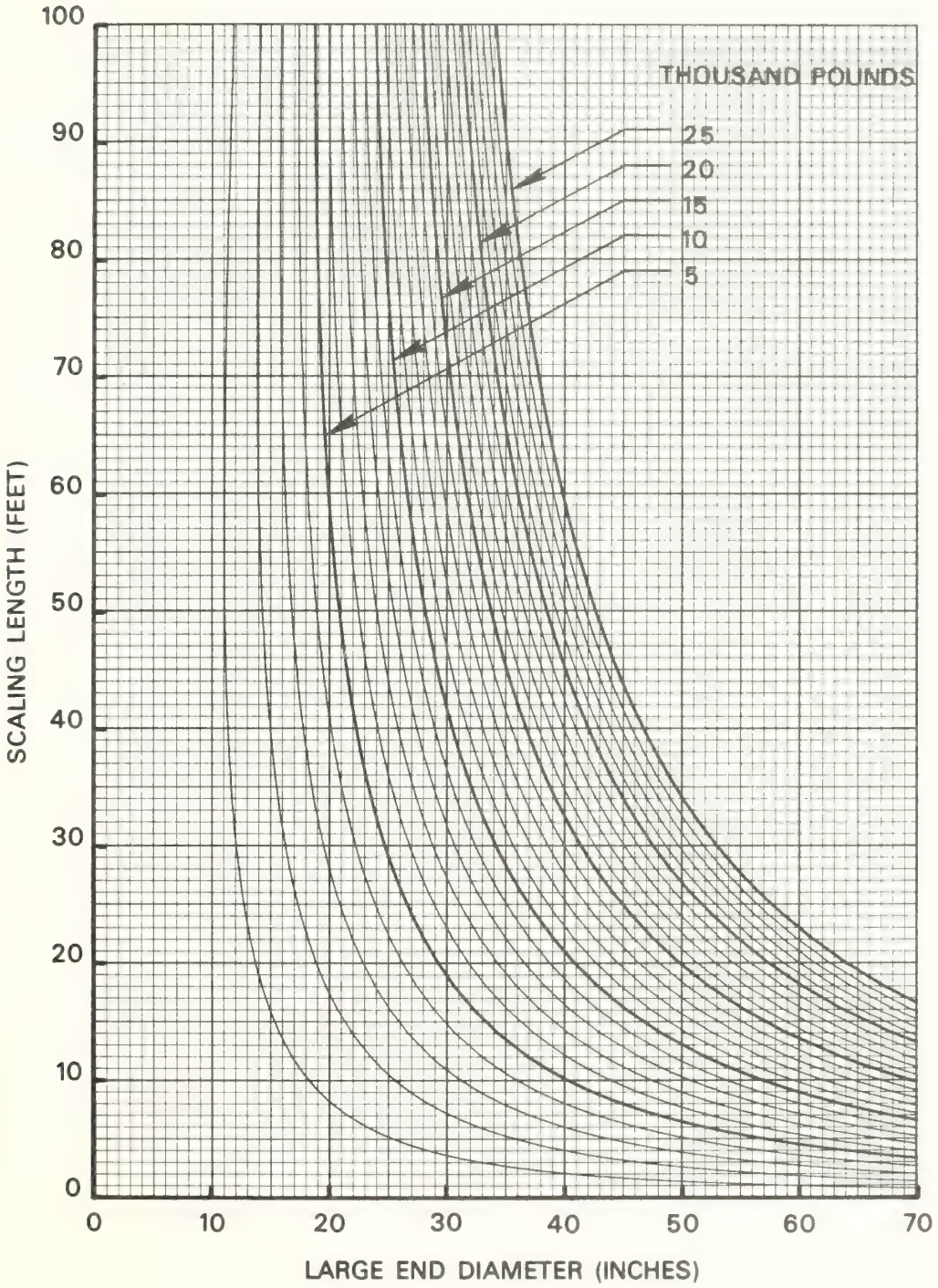


Figure 19.—Scaling length versus large end diameter for various log weights. Density index = 58 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

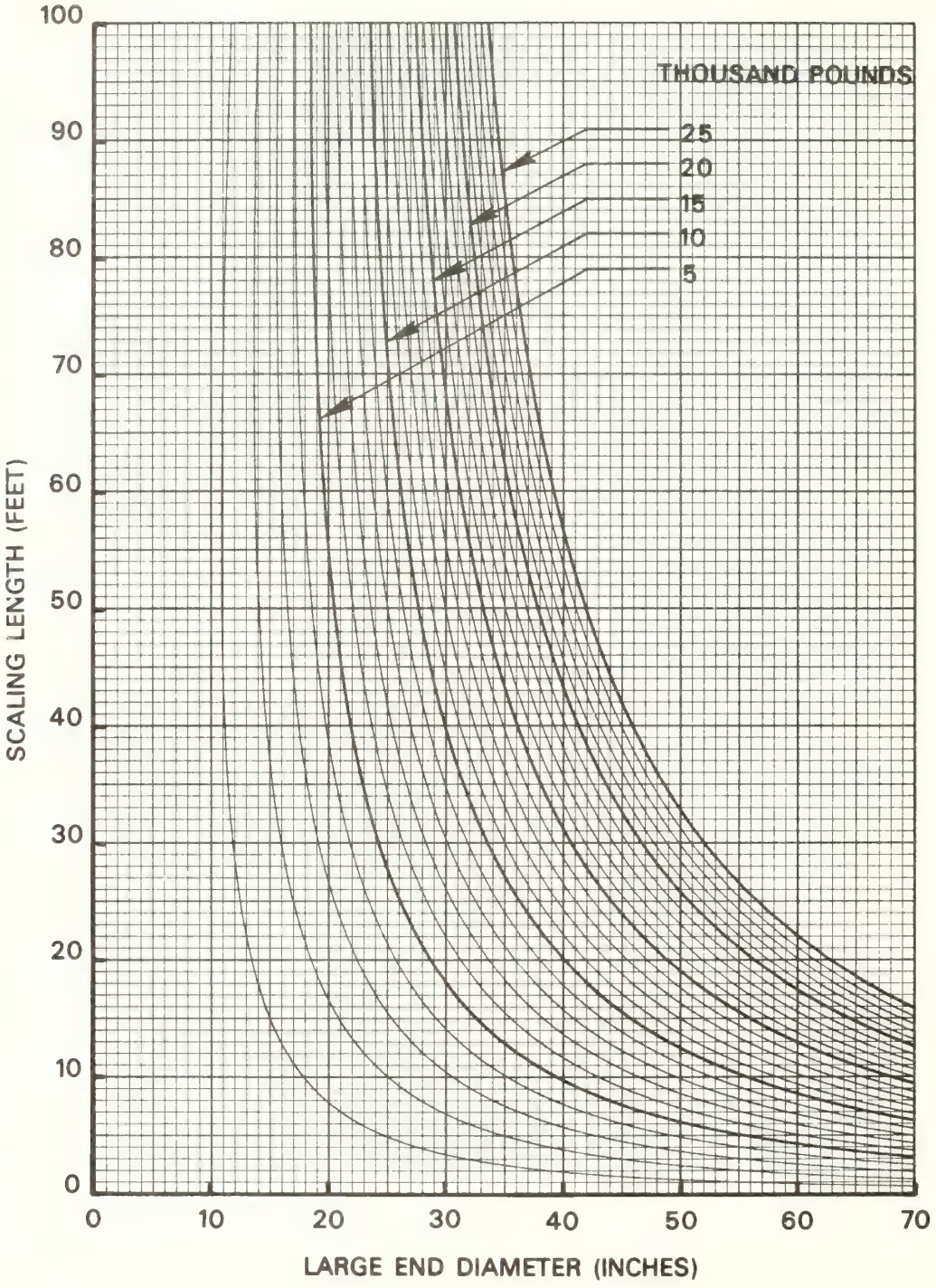


Figure 20.—Scaling length versus large end diameter for various log weights. Density index = 60 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

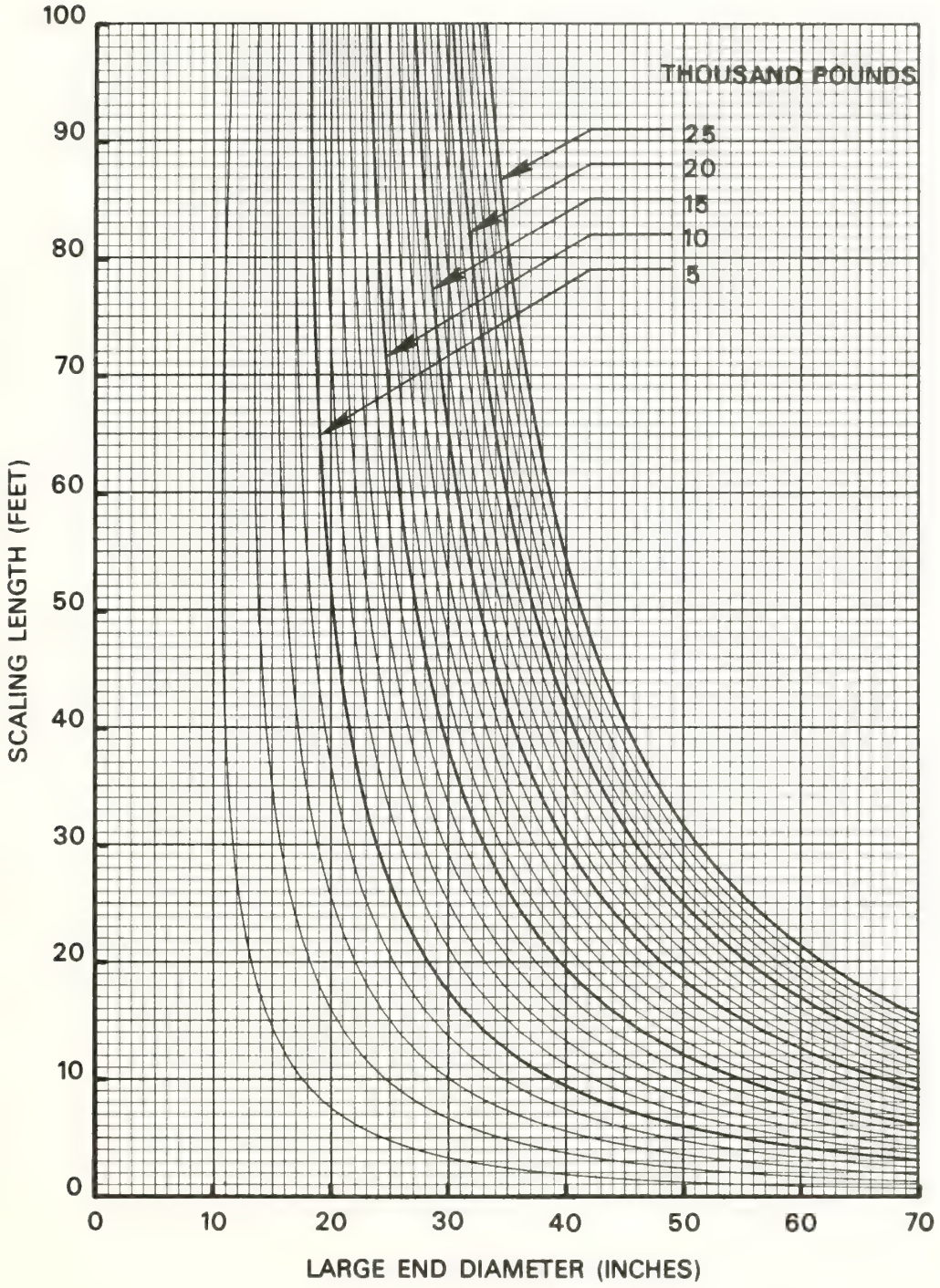


Figure 21.—Scaling length versus large end diameter for various log weights. Density index = 62 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

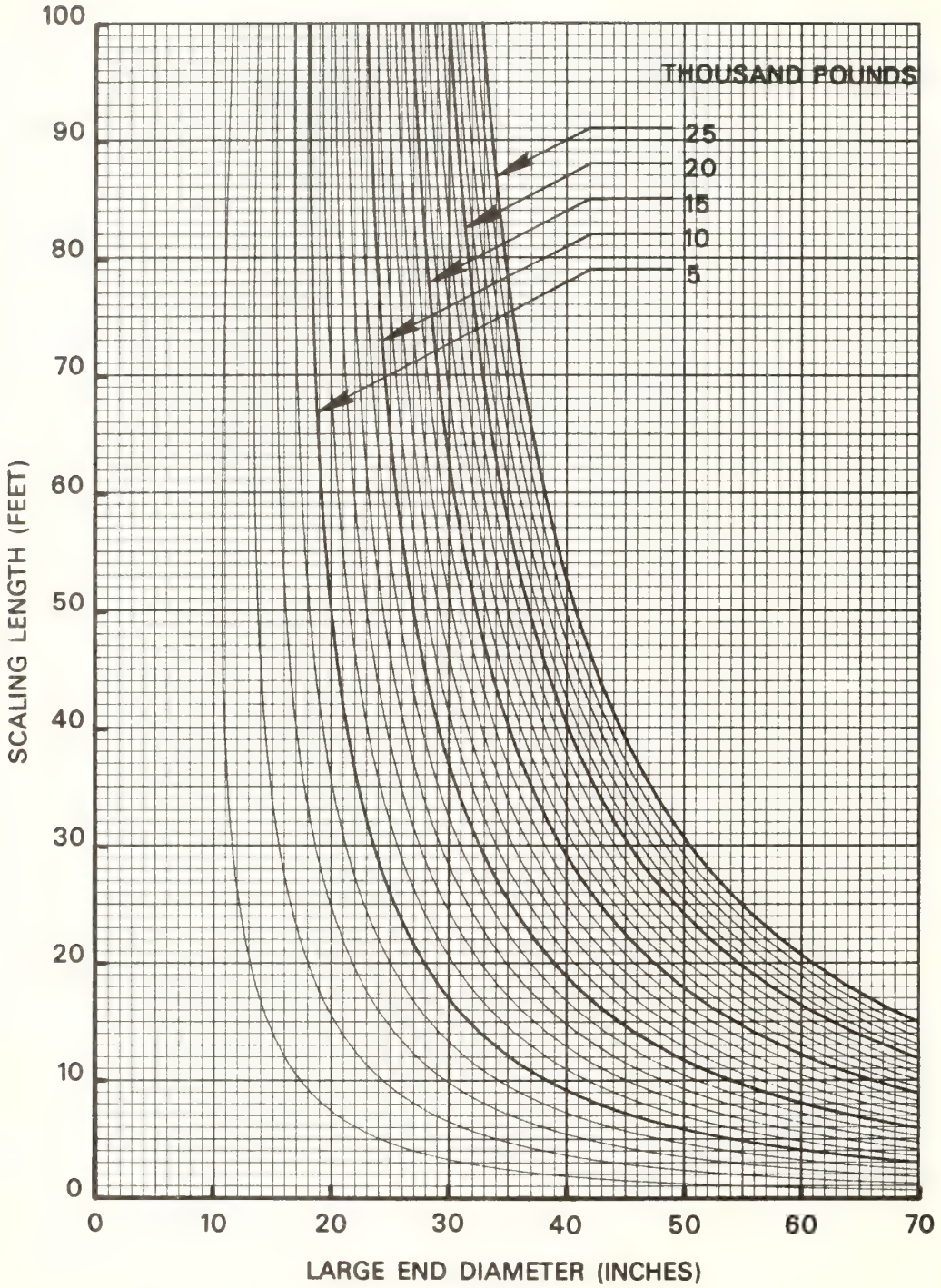


Figure 22.–Scaling length versus large end diameter for various log weights. Density index = 64 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

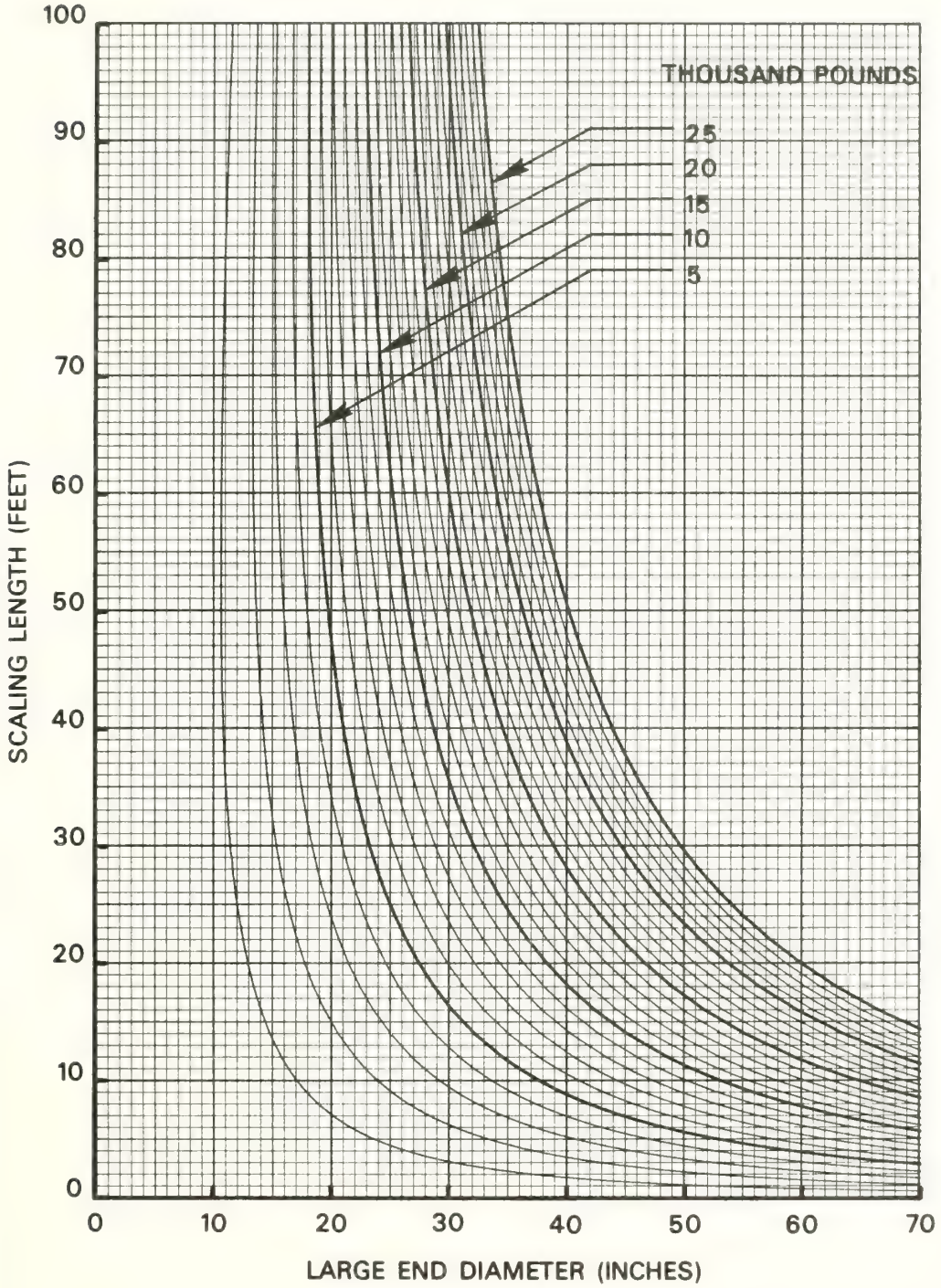


Figure 23.—Scaling length versus large end diameter for various log weights. Density index = 66 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

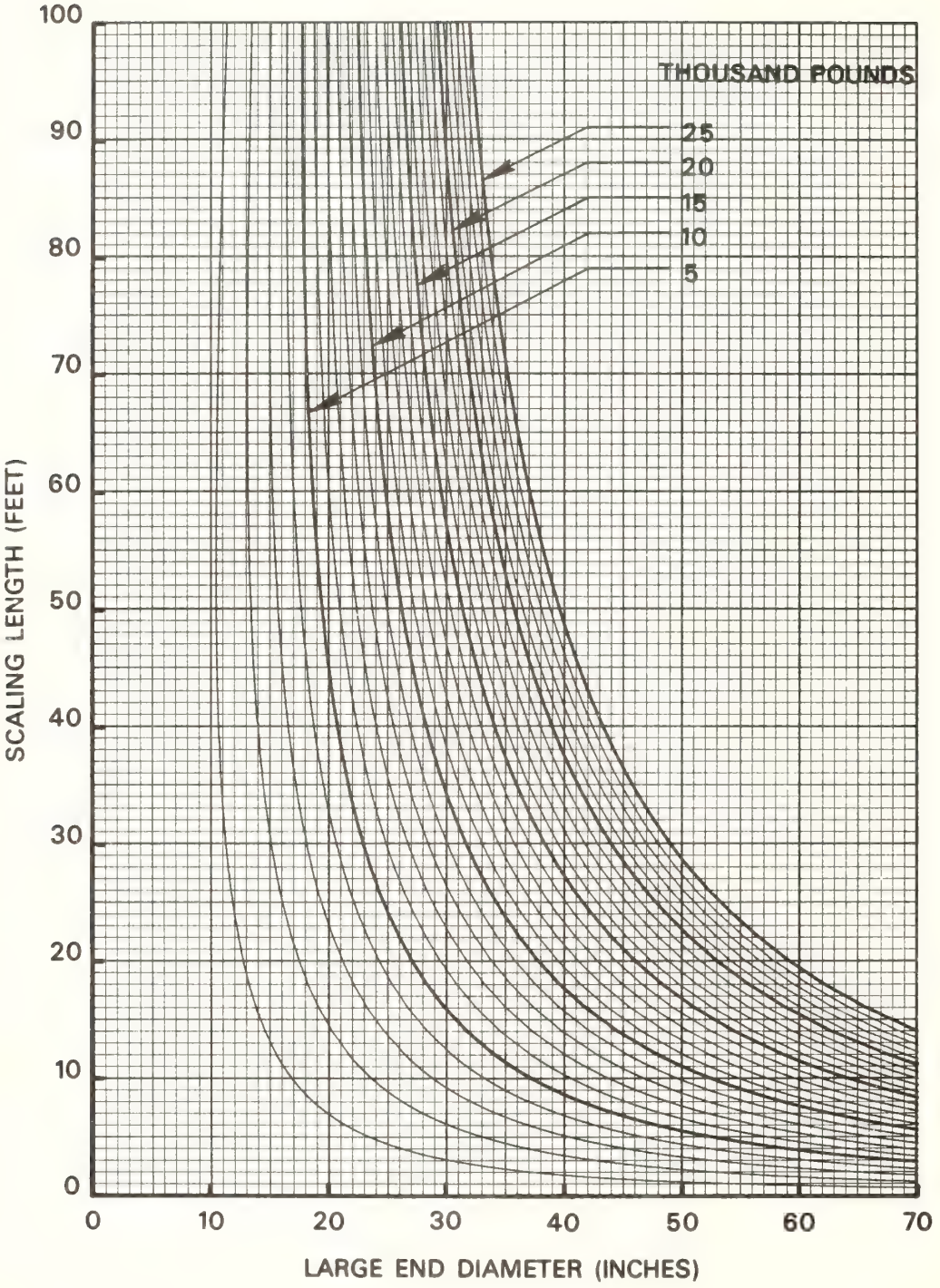


Figure 24.—Scaling length versus large end diameter for various log weights. Density index = 68 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

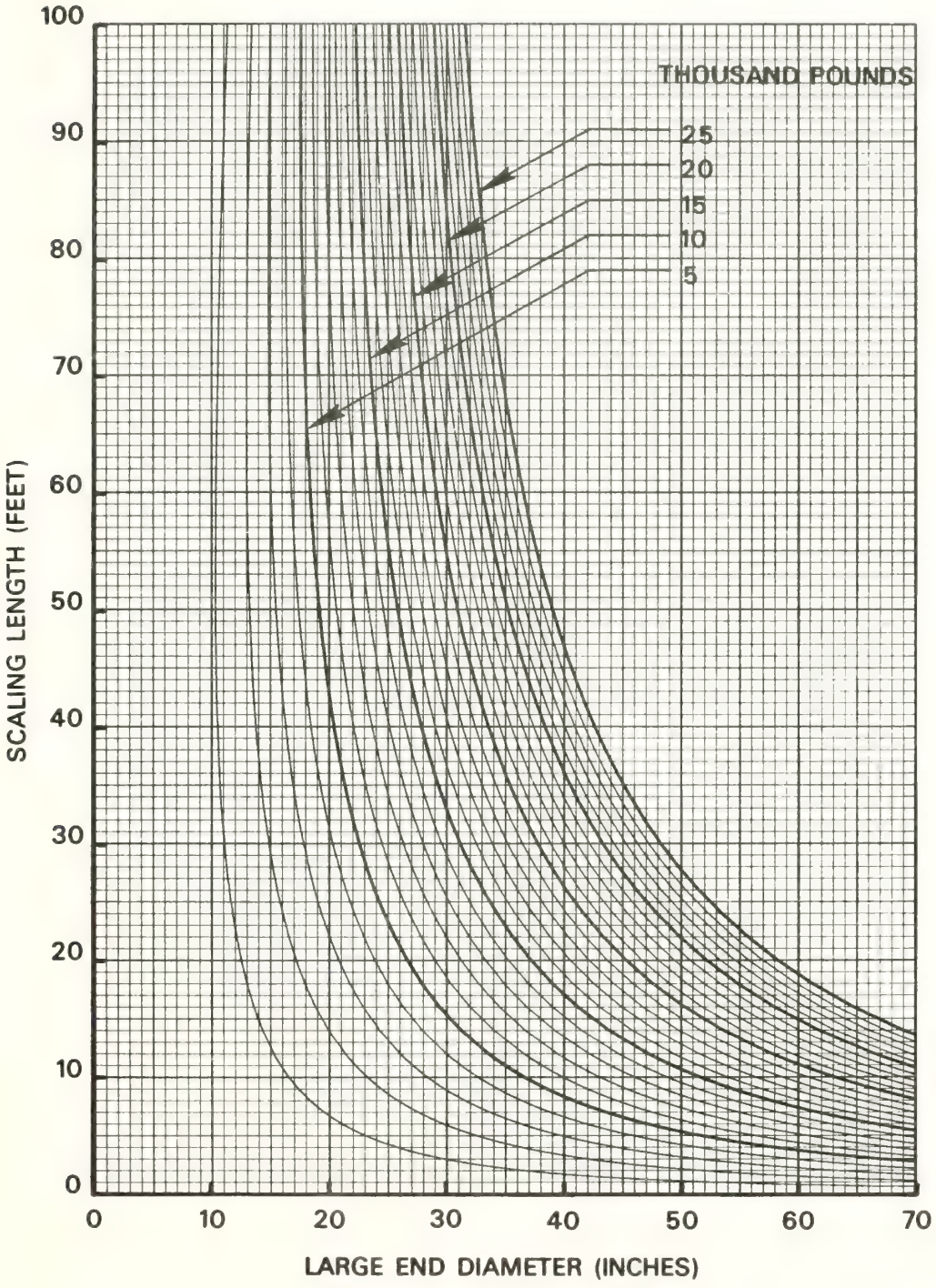


Figure 25.—Scaling length versus large end diameter for various log weights. Density index = 70 pounds per cubic foot. (Assumed taper of 1 inch per 8 feet, trim allowance of 1 inch per 4 feet.)

Figure 26.—Density index worksheet.

Sample No. _____ Date _____ Truck No. _____ Load No. _____

Gross weight _____lbs. Logging site _____

Tare weight _____lbs. Species _____

Net log weight _____lbs.

Scaling length[1] (feet)	Large end diameter (outside bark, inches)	Volume[2] (cubic feet)	Scaling length[1] (feet)	Large end diameter (outside bark, inches)	Volume[2] (cubic feet)

Figure 27.—Worksheet for moving average of density index.

Logging site _____ Species _____

Sample number	Date of sample	Sample density index	Moving total of density index[1/]	Current moving average[2/]

[1/] Add newest sample and delete oldest sample which was included in previous total.

[2/] Divide moving total by number of sample in moving average.

Mann, Charles N., and Hilton H. Lysons
1972. A method of estimating log weights. USDA Forest Serv. Res. Pap. PNW-138, 75 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

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Keywords: Logs, weights, logging.

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Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

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2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

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1972
USDA FOREST SERVICE RESEARCH PAPER PNW-139

THE RECORDING QUIZBOARD:

A DEVICE FOR EVALUATING INTERPRETIVE SERVICES

J. ALAN WAGAR

ACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
.S. DEPARTMENT OF AGRICULTURE · FOREST SERVICE · PORTLAND, OREGON

ABSTRACT

Describes design and use of recording quizboard which records right and wrong answers to questions based on visitor center exhibits. This helps determine how well exhibit messages are reaching visitors. Initial results indicate that taped messages are more effective than those a visitor must read.

Keywords: Exhibits, education, natural history.

The author is leader of the Environmental Interpretation Research Project maintained by the Pacific Northwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, in cooperation with the University of Washington, Seattle.

Special gratitude is expressed to Dr. John D. Schultz, Chairman of the Department of Forest Science, University of Alberta, who administered the 1970 data collection while a Naturalist at Mount Rainier National Park.

INTRODUCTION

As more and more areas have been set aside for recreation or for their natural, scenic, or historic importance, the number of programs and facilities designed to interpret these areas has also grown. The prevalence and popularity of these interpretive services show that both administrators and visitors consider them worthwhile. Yet there are few criteria for determining how worthwhile.

One of the great needs in the field of interpretation is to evaluate effectiveness. Do facilities and programs really have the effect they are intended to have? Interpreters have learned much by careful observation of visitors' reactions to these facilities and programs, but they could learn even more if visitors had a convenient way to register their reaction to interpretive services. Such "feedback" from visitors is needed to help the interpreter know how well he is doing and what changes might be useful.

As one effort to provide this kind of feedback, a recording quizboard was developed and tested (fig. 1). This simply presents the visitor with four multiple-choice questions and records his answers with electric impulse counters. When the questions are based on information provided by interpretation, answers indicate what ideas are or are not reaching the visitors who play the quizboard. When changes are made in a presentation, the quizboard can quickly detect whether the communication of specific information was improved.

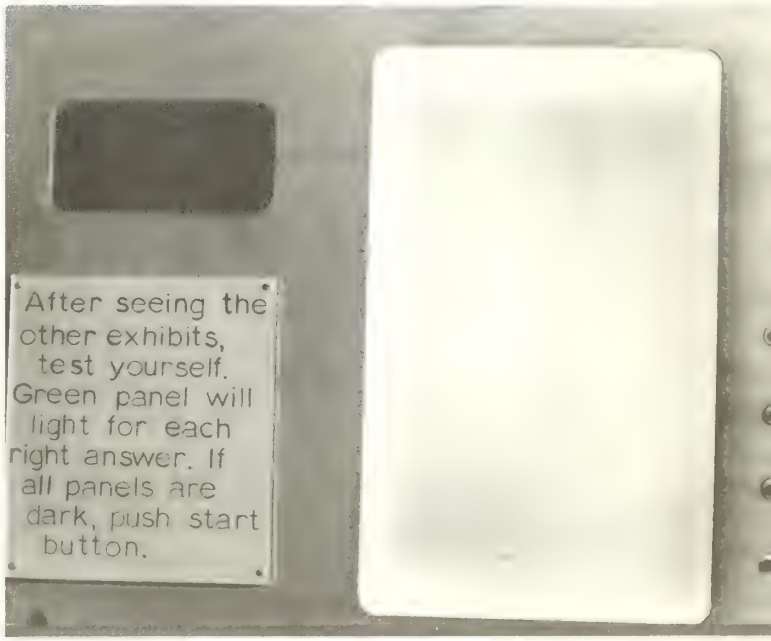

After seeing the other exhibits, test yourself. Green panel will light for each right answer. If all panels are dark, push start button.

Figure 1.--A, *Recording quizboard in use at Ohanapecosh Visitor Center, Mount Rainier National Park;* B, *question arrangement on backlighted panel.*

CONSTRUCTION AND OPERATION

The basic plan of the recording quizboard is simple. Four questions--each with four answer choices--are presented so that visitors can respond by pushing buttons. Unknown to the visitors, electric counters record their responses and provide a total count of correct and incorrect responses to each question. Thus, what visitors consider a game becomes a feedback and evaluation device for the interpretive planner.

The circuitry of the quizboard is designed so that only one panel is lighted and only one set of buttons is energized at a time. When a question is correctly answered, that question panel darkens, the next question panel lights up, and a green panel reading "right answer" lights up (providing reinforcement to the visitor).

Experience with an earlier version of the recording quizboard showed that some visitors--especially children--would push "correct" buttons repeatedly to see the green panel light up. Thus, the one-at-a-time panel lighting is important. This is accomplished by a rotating relay. As shown in the wiring diagram (fig. 2), additional relays are used to handle the amperage needed for counters and to avoid arcing on the push-buttons. A time delay relay is used to assure proper timing of other components.

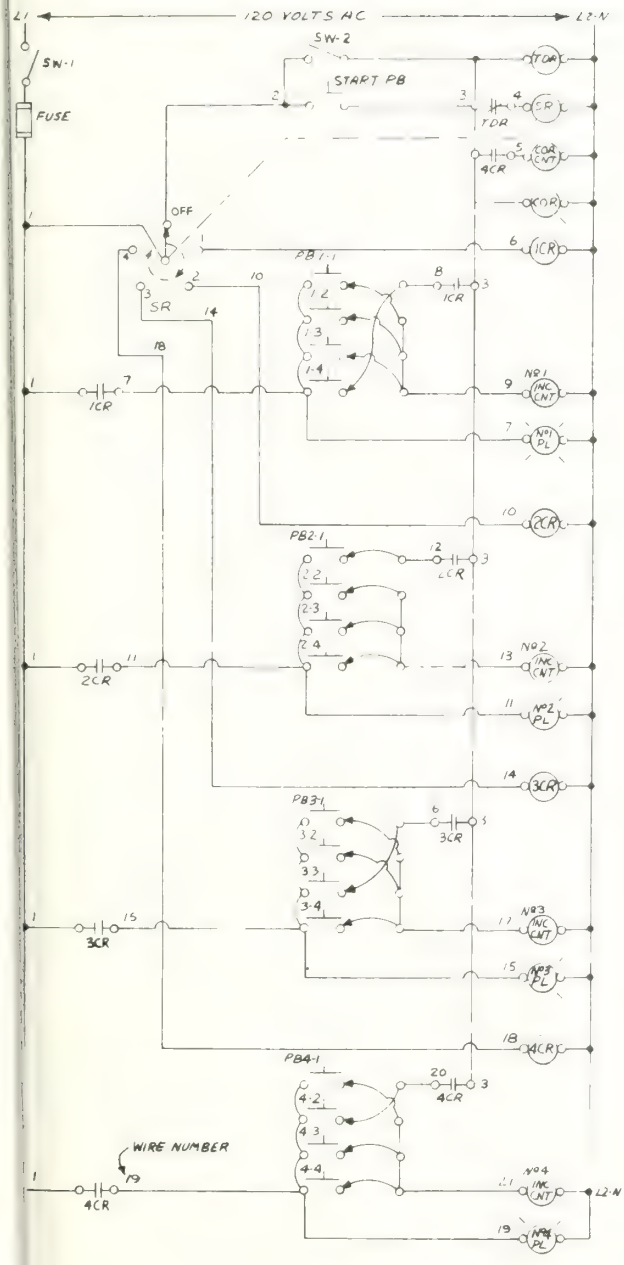
Because the "correct" button for a question must be pushed before the next question panel will become operative, one "correct" answer counter is sufficient to record the number of four-question sequences completed; however, a separate "incorrect" counter is required for each question (fig. 3A).

Correct and incorrect answer positions can be quickly changed by arranging 16 plugs on a small wiring board (fig. 3A). A green plug for each panel corresponds to the "correct" answer position and three red plugs correspond to the "incorrect" answer positions for that panel.

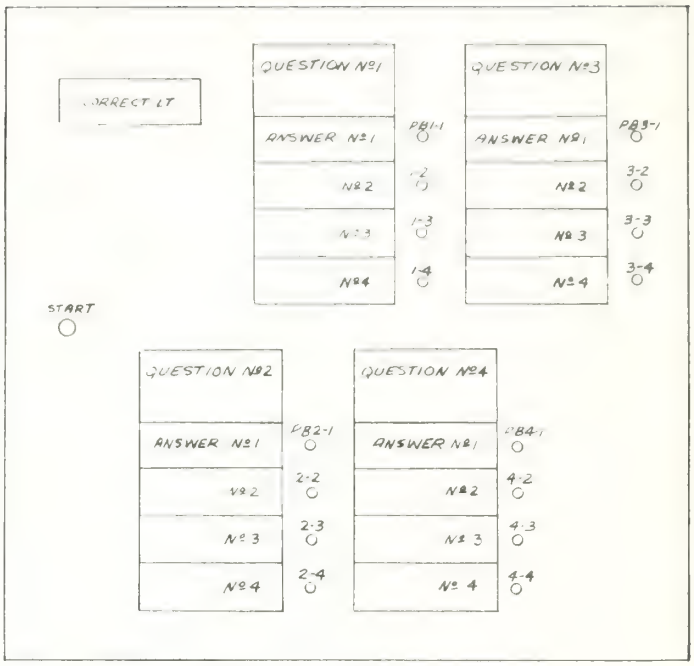
The quizboard was also designed for quick changes of question material. Questions can be typed (in oversize type) on tracing paper that is sandwiched between two sheets of acrylic plastic--a transparent gray sheet in front and a clear sheet in back (fig. 3B). The gray plastic sheet covering each question insures that it is readable only when illuminated from behind. The "sandwiches" are quickly slipped into the quizboard face which is removable (fig. 3C).

Each question panel is lighted by two showcase lights mounted against reflectors made of sheet aluminum (fig. 3D). A 40-watt bulb illuminates the "correct answer" panel. Wood and sheet metal form boxes to separate panel lighting.

The cost of components and materials for the recording quizboard was approximately $215.



WIRING DIAGRAM



PANEL ARRANGEMENT
NOT TO SCALE

LEGEND

SW1 & SW2 – TOGGLE SWITCH – SPST – 6 AMPS AT 125 VOLTS

FUSE – 5 AMPS

STEPPING RELAY – 10 STEPS – 120-VOLT COIL – PRINTED CIRCUIT BOARD SWITCH RATED 25 AMP. NOTE WIRE POINTS 1 &6, 2 & 7, 3 & 8, 4 & 9, AND 5 & 10 TOGETHER FOR 5-STEP ACTION

CONTROL RELAY – 3PDT – 10 AMP CONTACTS – 120-VOLT COIL RELAYS 2CR, 3CR, AND 4CR ARE THE SAME

RELAY CONTACT – NORMALLY OPEN

RELAY CONTACT – NORMALLY CLOSED

TIME DELAY RELAY – SPST – NORMALLY CLOSED – 2-SECOND TIME DELAY – 115-VOLT COIL

COUNTER – DIGITAL WITH 4 DIGITS AND MANUAL RESET KNOB – 120-VOLT COIL
INC = INCORRECT COR = CORRECT

J1-1 JACK (for panel 1, position 1)

BANANA PLUG

PUSHBUTTON – SPST – NORMALLY OPEN – 3 AMPS AT 125 VOLTS

CORRECT ANSWER LIGHT – 120 VOLTS

CORRECT PANEL LIGHT FOR NUMBER INDICATED – 120 VOLTS

Figure 2.--*Wiring diagram for the recording quizboard.*

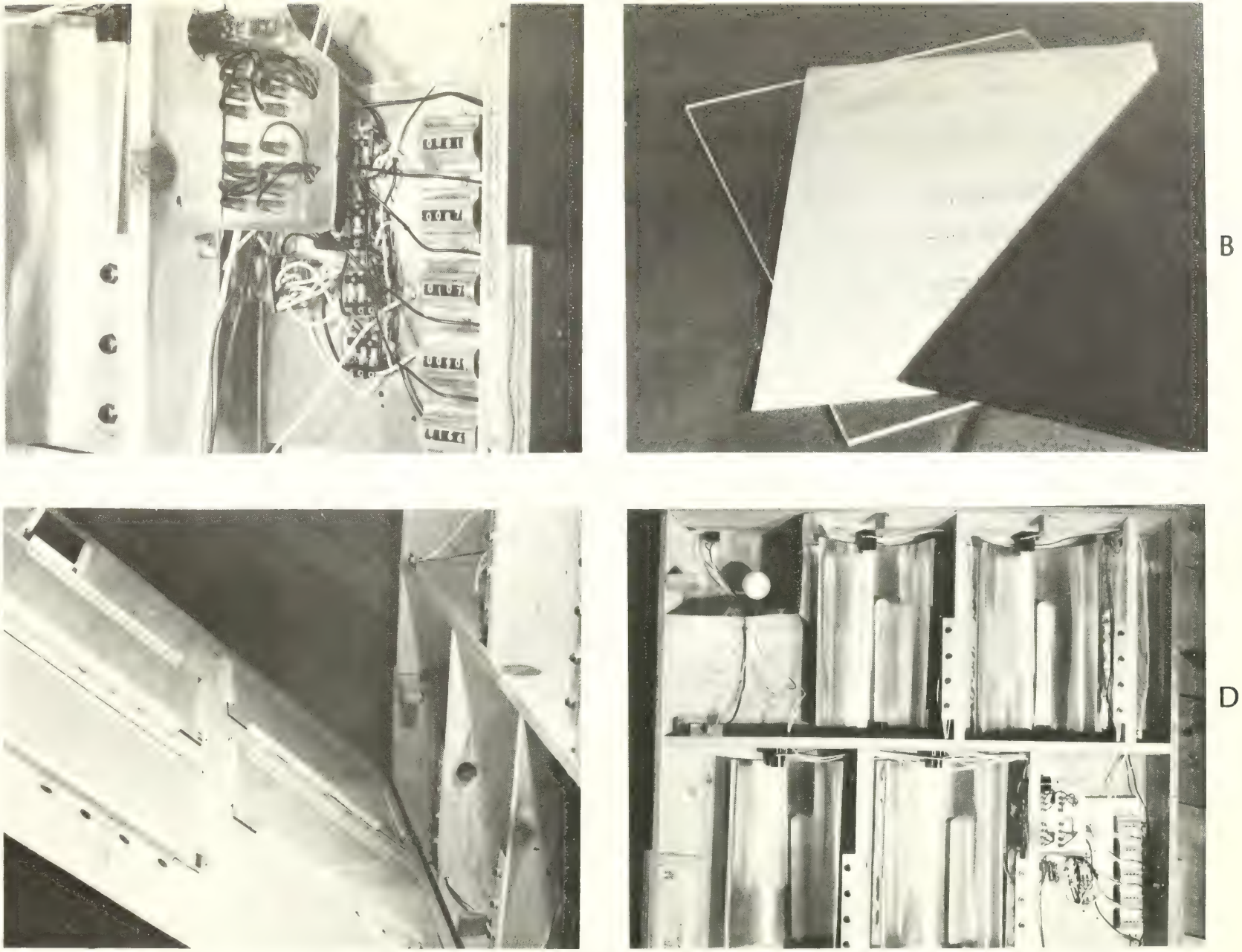


Figure 3.--*Construction detail for the recording quizboard: (A) Counters and the wiring board for defining which buttons operate which counters. Each group of four plugs includes a green plug for correct answer and three red plugs for incorrect answers. (B) Each answer panel contains a "sandwich" of tracing paper and sheets of acrylic plastic. (C) The removable quizboard face permits answer panels*

TESTING

The quizboard was tested at the Ohanapecosh Visitor Center in Mount Rainier National Park during August and September of 1969 and late July and August of 1970. This is a small visitor center devoted to interpreting the interrelationships of various life forms within the lowland forest portion of the Park. Exhibits are of excellent quality; and except for those designed to orient the visitor, all are pertinent to the central theme of the visitor center.

The 10 questions shown in table 1 were written to measure visitors' retention of specific information presented in the exhibits. The main purpose of testing was to see if the quizboard could distinguish between the effectiveness of different presentations. Questions were therefore based on a variety of exhibits incorporating different presentations. Specific comparisons were made between audio and text presentations and between various combinations of three-dimensional (3-D) and such "flatwork" presentations as photos and drawings. Questions 1 and 2 (for taped narration) were based on the recorded message of the key exhibit of the center, a diorama presenting mounted mammals and birds in a lifelike setting. When a button at this diorama was pushed, a recording explained predator-prey relationships and interactions between the plant and animal communities of the forest. Lighting was coordinated with the message to illuminate whichever animals were being discussed.

Questions 3, 4, and 5 (for 3-D and text) were based on the texts of small signs around a relief model of Mount Rainier National Park. Questions 6, 7, and 8 (for combinations of 3-D, flatwork, and text) were based on texts in three display cases interpreting the three major trees of the area--Douglas-fir, western redcedar, and western hemlock. These cases included photographs and drawings along with such 3-D objects as upright sections of bark, mounted birds, and Indian artifacts. Questions 9 and 10 (for flatwork and text) were based on panels that included only photographs, drawings or paintings, and text.

For the 1969 tests, these questions were used in three sets of four as follows:

1, 2, 9, 10;
1, 3, 4, 5; and
1, 6, 7, 8.

Results for 1969 were distorted because of a faulty counter but suggested that visitor responses changed after Labor Day, when an older group predominated in the adjacent campground. After Labor Day the proportion of correct answers went up for all questions. The 1969 results also indicated that the position of the correct answer among the four choices might be affecting results.

Because of the 1969 results, procedures were changed in 1970. To eliminate position effects, each of the 10 questions was written four ways, with the correct answer placed in each of the four possible positions. This gave a total of 40 questions presented in 12 sets of four. These were presented so that (1) two versions of the same question were never used at the same time, (2) a version of question 1 was included in

Table 1.-- *Questions used with the recording quizboard, Ohanapecosh Visitor Center*[1/]

Number	Question	Answer choices	Position
1	If there were no flesh eating animals, the plant eating animals of the forest	would not worry so much and be fat and healthy	a
		would be much more numerous	b
		would destroy their food supply by eating more than the forest could produce	c
		would not be affected	d
2	The creature most likely to be found eating berries is	the coyote	a
		the grouse	b
		the bobcat	c
		the martin	d
3	Each National Park is established by an Act of Congress. Mount Rainier was	established in 1890	a
		established in 1899	b
		established in 1906	c
		established in 1916	d
4	Caverns at the summit of Mount Rainier have been used	for geodetic research	a
		as a refuge for marooned climbers	b
		by hibernating bears	c
		as cold storage for the kitchen at the lodge	d
5	Outside of Alaska, Mount Rainier	is the tallest mountain in the U.S.	a
		has the largest glacier system in the U.S.	b
		has the highest recorded wind in the U.S.	c
		is the most northerly volcano in the U.S.	d
6	Indians of the Northwest made baskets, clothing, and other articles from the fibrous bark of	red alder	a
		Douglas-fir	b
		western hemlock	c
		western redcedar	d
7	A bird that cracks seed with its heavy bill is the	evening grosbeak	a
		red-shafted flicker	b
		gray jay	c
		western tanager	d
8	Rotting logs, with their nutrients and moisture, often provide a starting place for seedlings of	true firs	a
		western hemlock	b
		Douglas-fir	c
		western white pine	d
9	In forest succession, hemlock tends to replace Douglas-fir	because hemlock is more resistant to fire, insects, and other destructive agents	a
		because hemlock lives longer than Douglas-fir	b
		because hemlock grows faster than Douglas-fir	c
		because hemlock seedlings survive better than Douglas-fir seedlings in the shade of a mature forest	d
10	Principal agents in reducing litter to humus are	fungi	a
		freezing and thawing	b
		insects	c
		rodents	d

[1/] In 1970, each of the 10 questions was used with four different arrangements of answer choices, providing versions with the correct answer in positions a, b, c, and d (correct choice is italicized).

each set (causing each version to be used in three of the 12 sets), and (3) all other questions were used just once. Within these constraints, questions were assigned to question sets at random.

Each question set was used until the "correct" counter registered at least 500 counts, insuring approximately even amounts of play for each set of questions. Data accumulated so rapidly that all question sets were used twice.

RESULTS

Proportions of correct answers for the 10 basic questions and four answer positions are shown in figures 4 and 5. These results correspond to interest patterns found in an interview study in which visitors at Ohanapecosh and four other visitor centers were asked to designate the exhibits they found most interesting.[1/] The exhibits shown by interviews to be the most and least interesting were those the recording quizboard showed to have the highest and lowest retention of information.

Statistical analyses were made to test for dependable differences (a) between specific groups of questions, (b) among all questions, and (c) among answer positions. These tests indicated that visitors remembered more from the exhibit with taped

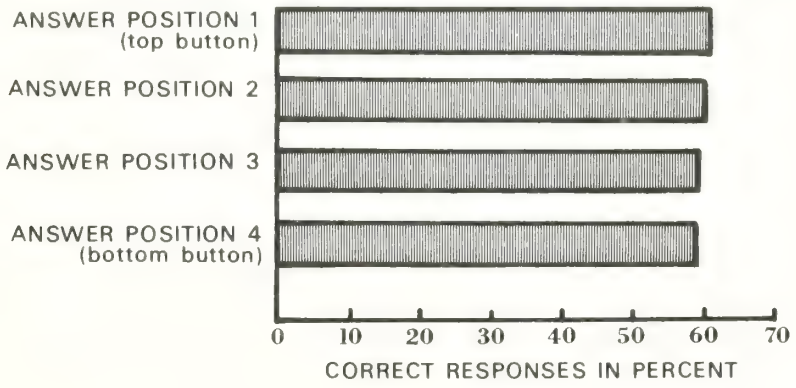


Figure 4.--*The effect of answer position for the recording quizboard. Data for all 10 questions having the correct answer in position 1 were combined, as were data for each set of 10 questions having correct answers in positions 2, 3, and 4, respectively. Since equal amounts of data were used for all 40 questions, this grouping averaged out the effects of content within each set of 10 questions.*

[1/] Randel F. Washburne. Visitor response to interpretive facilities at five visitor centers. Unpublished Master's thesis, University of Washington, Seattle. 91 p., 1971.

Question

The creature most likely to be found eating berries is the *grouse*.

If there were no flesh eating animals, the plant eating animals of the forest *would destroy their food supply by eating more than the forest could produce.*

Each National Park is established by act of Congress. Mount Rainier was established in *1899*.

Rotting logs, with their nutrients and moisture, often provide a starting place for seedlings of *western hemlock*.

Indians of the Northwest made baskets, clothing, and other articles from the fibrous bark of *western redcedar*.

Outside of Alaska, Mount Rainier has the *largest glacier system in the U.S.*

In forest succession, hemlock tends to replace Douglas-fir *because hemlock seedlings survive better than Douglas-fir seedlings in the shade of a mature forest.*

Principal agents in reducing litter to humus are *fungi*.

Caverns at the summit of Mount Rainier have been used *as a refuge for marooned climbers.*

A bird that cracks seed with its heavy bill is the *evening grosbeak*.

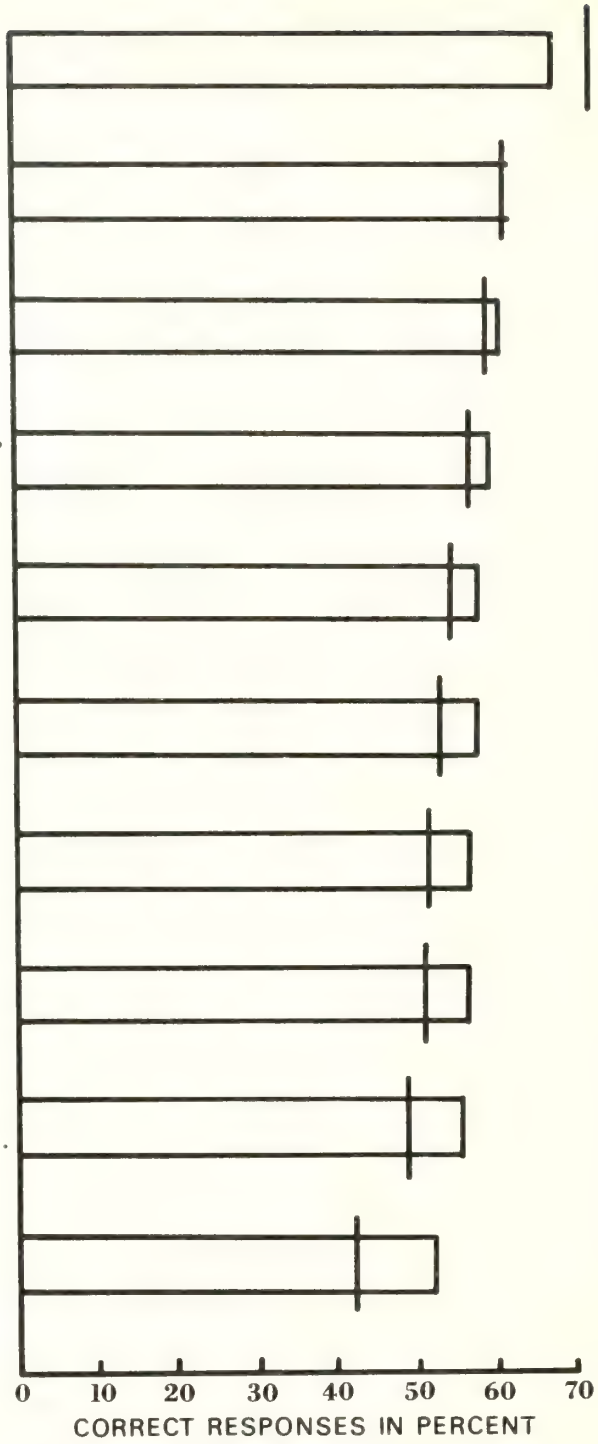


Figure 5.--*Results obtained by the recording quizboard, Ohanapecosh Visitor Center, Mount Rainier National Park, 1970. Bars indicate correct answer percentages obtained. Vertical lines show these percentages corrected for an assumed pattern in which one out of four plays was either random or systematic and another one out of four plays was correct because answers had been memorized during previous playing of the quizboard.*

narration (represented by questions 1 and 2) than from exhibits with written texts. Specifically, the tests permit us to be 99 percent sure that correct answer proportions for questions 1 and 2 combined are dependably higher than for all other questions combined. For comparisons among all questions, the tests permit us to be 95 percent sure that the correct answer proportion for question 2 is dependably higher than the correct answer proportion for question 4, 7, 9, or 10.

Tests indicate a 90-percent likelihood that the position of the correct answer affects the proportion of answers that are correct--some visitors push answer buttons systematically, as from top to bottom.

A particularly interesting result from this study was the popularity of the quizboard with children. Although the exhibits at Ohanapecosh are of excellent quality, the quizboard was the only item in the entire visitor center a child could manipulate. Within seconds after its installation, it became, for children, the most popular exhibit in the center.

DISCUSSION

Results show that the recording quizboard can tell the interpretive planner which questions are being answered correctly most often and can provide feedback that helps him determine the relative effectiveness of various exhibits or other interpretive efforts. Such feedback should be especially helpful for determining whether a change in a presentation makes it more effective or less so in conveying specific information to visitors.

The quizboard, however, cannot always identify the exact reason a presentation is effective. Interpretive planners often seem to use their most effective techniques for their most exciting stories. For example, at the Ohanapecosh Visitor Center, questions based on the diorama with a recorded message were answered more correctly than others. Yet this could be explained by the use of a taped message, by exciting subject matter (predators and prey), by exhibit size (largest in the building), by realism (unmatched by other exhibits in the building), or even by the possibility that visitors knew much of the subject matter before seeing the exhibit.

Because visitors who play the recording quizboard are a self-selected group, results will not represent the average of all visitors. Nevertheless, they may still provide the best available indication of what visitors are learning.

Differences between answers are reduced but not obscured by both repeated play and random or systematic play of the quizboard. At the Ohanapecosh Visitor Center, repeated play by children from the adjacent campground was especially common and accounted for a substantial portion of the total data. The usual pattern for a young "repeater" was to play until he learned the correct answers, play for several correct sequences, and then find someone else to watch him "get them all right."

To examine the effects of nonserious playing, I made computations for assumed amounts of such playing. For purposes of illustration, computations were made as if 25 percent of all answers were repeated plays in which all answers were correct

because of prior memorization and as if another 25 percent of the answers resulted from random or systematic playing.[2/]

The lines across the bars of figure 5 show results adjusted to exclude these assumed levels of nonserious play. Note that, in terms of correct answers, nonserious play does not change the order of questions but simply decreases differences between questions. This indicates that recording quizboards will give the most sensitive tests of interpretive effectiveness when located where they will be used primarily by transient visitors who are unlikely to play them repeatedly. In locations that encourage repeated play, as near overnight accommodations that hold visitors in an area for several days, results will be conservative and will show smaller differences than could be expected if all playing were serious.

Because playing the quizboard is obviously rewarding to many visitors, especially children, it can focus attention on specific information, thereby serving a teaching as well as a feedback function. The next step is to harness this reward pattern to enhance learning of more detailed concepts than are suited to quizboard question panels. A study of these possibilities is underway.

CONCLUSIONS AND RECOMMENDATIONS

1. Recording quizboards can be effective for obtaining feedback from visitors to indicate what they know or have learned. Quizboards should be especially good for detecting the effects of changes in interpretive facilities or presentations.

2. For the questions it presents, a recording quizboard can detect real differences in proportions of correct responses made during serious playing, even if many visitors either play it repeatedly after memorizing answers or play it randomly or systematically. The effect of nonserious play is to reduce differences between proportions of correct answers. However, the order of results will not be changed.

3. The positions of correct answers are likely to affect proportions of correct responses. Several versions of each question should therefore be written so that correct answers appear in each position for approximately the same number of responses. For four-choice questions, this requires four versions of each question. These should be rotated every 500 or 1,000 responses according to a randomly determined schedule.

[2/] Question 2 had a correct-answer ratio of 676/1000. If a quarter of all answers were correct because of prior memorization, the correct-answer ratio would change to (676 - 250) : (1000 - 250). Since all four answer positions were used an equal number of times, the effects of systematic and random answering would be identical. If another quarter of the responses were either random or systematic, one out of four answer choices (250/4 = 62.5) would be correct. This would further change the correct-answer ratio to (676 - 250 - 62.5) : (1000 - 250 - 250) = 0.727, an increase. At the other end of the scale, question 7 with a correct-answer ratio of 521/1000 would become (521 - 250 - 62.5) : (1000 - 250 - 250) = 0.417, a decrease. Subtracting other assumed amounts of nonserious answering also increases differences between correct-answer ratios for different questions.

4. When a recording quizboard is first used in a new setting, statistical tests should be made to determine how large differences between answers must be to be statistically significant. Thereafter, such tests should not be necessary. Approximately 1,000 responses for each version of each question should provide data with adequate stability for comparisons to be made between questions.

STATISTICAL ANALYSIS

Although chi-square analysis was originally planned for the recording quizboard, observations were not suitably independent. This lack of independence resulted from repeated playing by some individuals and from the fact that most people answered all four questions.

Because chi-square analysis was not appropriate, an analysis of variance was made. In this, the ratio of right answers to total answers was computed for each version of each question, giving 40 ratios (four versions each for 10 questions). Each ratio resulted from approximately 1,000 answer choices for the version and question involved. Although this does not seem to provide efficient use of each observation, large numbers of observations are easily obtained.

Analyses were made both with and without weighting for the number of observations on which each ratio was based. Results of these analyses were essentially identical, and only the unweighted analysis is reported (table 2).

Table 2.--*Analysis of variance for quizboard data, Ohanapecosh Visitor Center, 1970*

Source	d.f.	Sum of squares	Mean squares	F	P
Questions	9	0.06372	0.00708	3.91	<0.01
Answer positions	3	.01414	.00471	2.61	<.10
Error	27	.04887	.00181		
Total	39				

This analysis permits us to be 99 percent sure that means for the ratios of right answers to total answers differ among the questions. The analysis also permits us to be 90 percent sure that means of these ratios differ according to the position of the correct answer.

Comparisons

Designed comparisons were made to test for differences between questions based on three different patterns of exhibits: a diorama with recorded narration, 3-D exhibits

with text labels, and flatwork exhibits with text labels. Coefficients for the comparisons are shown in figure 6.

Of the nine designed comparisons, two were significant at 95 percent or higher probability: Comparison 1 showed that the two questions based on the diorama with recorded narration had significantly more correct answers than the eight questions based on text; comparison 9 showed that, for information presented on text labels in exhibits combining both flatwork and 3-D elements, visitors gave the correct answer to a question on Indians significantly more often than to a question on the evening grosbeak. However, since the grosbeak was a minor element in a large display case, no generalization seems justified by the significant result for the comparison.

In addition to the designed comparisons, all comparisons among means for the 10 answer ratios were made using the Tukey test.[3/] In this, the minimum significant difference D was computed as

$$Q\sqrt{\text{error mean square}/\text{number of observations per mean}} = 4.88\sqrt{0.00181/4} = 0.1039$$

where Q is a table value for 10 treatments and 27 degrees of freedom.

Only four differences between means exceeded this value. These were as follows:

	Question 7	Question 4	Question 10	Question 9
Question 2	0.1552	0.1215	0.1086	0.1067

Comparison	Coefficients									
	Audio		3-D only, and text			3-D plus flatwork and text			Flatwork and text	
Question	1	2	3	4	5	6	7	8	9	10
Mean	.62195	.67628	.60960	.55475	.57867	.58540	.52105	.59730	.56958	.56770
1	+4	+4	-1	-1	-1	-1	-1	-1	-1	-1
2	+1	-1								
3			+1	+1	+1	+1	+1	+1	-3	-3
4			+1	+1	+1	-1	-1	-1		
5									+1	-1
6			+1	+1	-2					
7			+1	-1						
8						+1	+1	-2		
9						+1	-1			

Computations for comparisons 1 and 9, using procedures from p. 329-332 of George W. Snedecor (Statistical Methods, 5th ed., Iowa State College Press, Ames. 1956). (Note that means are multiplied by 4 to convert them to sums.)

Comparison 1 Sum of squares $= \frac{[2(.4875)+4(2.70512)-2.4384-2.2190-2.31469-2.3416-2.0842-2.3892-2.27832-2.2708]^2}{4(40)}$

$= 0.03707$ $F = \frac{0.03707}{0.00181} = 20+$ $P < .1$

Comparison 9: Sum of squares $= \frac{(2.3416-2.0842)^2}{4(2)}$

$0.0082+$ $F = \frac{0.00823}{0.00181} = 4.5+$ $P < 0.05$

Figure 6.--*Designed comparisons and orthogonal coefficient sets for recording quizboard data.*

[3/] George W. Snedecor. Statistical methods, p. 251-253. Ames, Iowa State Coll. Press, 1956.

GPO 796-26

Wagar, J. Alan
1972. The recording quizboard: a device for evaluating interpretive services. USDA Forest Serv. Res. Pap. PNW-139, 12 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Describes design and use of recording quizboard which records right and wrong answers to questions based on visitor center exhibits. This helps determine how well exhibit messages are reaching visitors. Initial results indicate that taped messages are more effective than those a visitor must read.

Keywords: Exhibits, education, natural history.

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The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

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Juneau, Alaska
Bend, Oregon
Corvallis, Oregon
La Grande, Oregon
Portland, Oregon
Olympia, Washington
Seattle, Washington
Wenatchee, Washington

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USDA Forest Service Research Paper PNW-140
1972

Questionnaires for Research:

An Annotated Bibliography on Design, Construction, and Use

Dale R. Potter
Kathryn M. Sharpe
John C. Hendee
Roger N. Clark

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE PORTLAND, OREGON

ABSTRACT

Questionnaires as social science tools are used increasingly to study people aspects of outdoor recreation and other natural resource fields. An annotated bibliography including subjective evaluations of each article and a keyword list is presented for 193 references to aid researchers and managers in the design, construction, and use of mail questionnaires.

Keywords: Bibliography, questionnaires, recreation, natural resources, public opinion surveys, research.

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Roger N. Clark is a Social Scientist with the Outdoor Recreation Research Project of the Pacific Northwest Forest and Range Experiment Station.

USDA FOREST SERVICE
Research Paper PNW-140

QUESTIONNAIRES FOR RESEARCH

An Annotated Bibliography on Design, Construction, and Use

by

Dale R. Potter
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1972

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
Robert E. Buckman, Director *Portland, Oregon*

Forest Service *U.S. Department of Agriculture*

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INTRODUCTION

This bibliography was compiled in response to frequent requests for information on questionnaires by outdoor recreation researchers and the increasing use and misuse of questionnaires by investigators studying public reaction in the area of natural resources.[1/] Questionnaires are a long standing tool for gathering data in social science research but are used increasingly by researchers and professional managers unfamiliar with the problems associated with their use in fields such as recreation and natural resource. The objective of this annotated bibliography is to make available a summary and appraisal of literature on the construction and use of questionnaires for research purposes.

Several features are built into the bibliography to increase its usefulness:

First, the annotations summarize the content and conclusions of the article rather than merely describing what the article is about. Of course, readers are forewarned against quoting annotations directly without first consulting the original source because our interpretation of the original paper may be different from theirs.

Second, accompanying most annotations is our subjective evaluation of the article. These evaluations may reflect different standards among the evaluators; nevertheless, they should be useful in helping readers decide which references warrant their further attention.

Third, each citation contains a list of keywords geared specifically to topics covered in the article. These keywords are the basis for the index in the back of the bibliography to guide readers to those aspects of questionnaires in which they might be interested.

In conclusion, readers contemplating the use of questionnaires are advised that the complexities of using questionnaires for research are often vastly underrated. The popularity of the method often rests on ignorance of associated problems of data analysis, bias, reliability, and validity of results.

Persons desiring publications included in this bibliography should consult the reference source cited or write to the agency which sponsored the reference. Neither the Pacific Northwest Forest and Range Experiment Station nor the authors can provide copies of any references listed in this bibliography.

[1/] Portions of this work were conducted under cooperative agreement between the Forest Service and the University of Washington College of Forest Resources.

ABBREVIATIONS FOR REFERENCE SOURCES

Am. J. Sociol.	American Journal of Sociology
Am. Sociol. Rev.	American Sociological Review
Am. Statist. Assoc. J.	American Statistical Association Journal
Assoc. Am. Coll. Bull.	Association of American Colleges Bulletin
Brit. Psychol. Soc. Bull.	British Psychological Society Bulletin
Educ. Admin. & Superv.	Education Administration and Supervision
Educ. & Psychol. Meas.	Education and Psychological Measurement
Educ. Res. Bull.	Educational Research Bulletin
Educ. Rev.	Educational Review
Int. J. Opin. & Attitude Res.	International Journal of Opinion and Attitude Research
J. Abnorm. & Soc. Behav.	Journal of Abnormal and Social Behavior
J. Abnorm. & Soc. Psychol.	Journal of Abnormal and Social Psychology
J. Adver. Res.	Journal of Advertising Research
J. Appl. Psychol.	Journal of Applied Psychology
J. Appl. Social.	Journal of Applied Sociology
J. Consult. Psychol.	Journal of Consulting Psychology
J. Educ. Psychol.	Journal of Educational Psychology
J. Educ. Res.	Journal of Educational Research
J. Exp. Educ.	Journal of Experimental Education
J. For.	Journal of Forestry
J. Juvenile Res.	Journal of Juvenile Research
J. Marketing	Journal of Marketing
J. Personality	Journal of Personality
J. Personnel Res.	Journal of Personnel Research
J. Psychol.	Journal of Psychology
J. Royal Statist. Soc.	Journal of the Royal Statistical Society
J. Soc. Issues	Journal of Social Issues
J. Soc. Psychol.	Journal of Social Psychology
N. Am. Rev.	North American Review
Pac. Sociol. Rev.	Pacific Sociological Review
Pedagog. Seminary	The Pedagogical Seminary
Personnel Psychol.	Personnel Psychology
Printers' Ink	Printers' Ink
Proc. Iowa Acad. Sci.	Proceedings Iowa Academy of Science
Psychol. Bull.	Psychological Bulletin
Publ. Opin. Quart.	Public Opinion Quarterly
Res. Bull. Natl. Educ. Assoc.	Research Bulletin of the National Education Association
Res. Quart.	Research Quarterly
Rev. Educ. Res.	Review of Educational Research
Royal Statist. Soc. J.	Royal Statistical Society Journal
Rural Sociol.	Rural Sociology
Sales Manage.	Sales Management
Sch. Rev.	The School Review
Sch. & Soc.	School and Society
Sociol. Abstr.	Sociological Abstracts
Soc. Forces	Social Forces
Soc. Probl.	Social Problems
Sociol. & Soc. Res.	Sociology and Social Research

ANNOTATED BIBLIOGRAPHY

1. Ash, Philip, and Edward Abramson
   1952. The effect of anonymity on attitude-questionnaire response. J. Abnorm. & Soc. Behav. 47(3): 722-723.

   Results from three attitude scales of ethnocentrism, political-economic conservatism, and anti-Negro prejudice administered to 96 college sociology students showed no significant difference between half the group required to sign answer sheets and half who remained anonymous.

   EVALUATION: Extension of results should be made with caution--students are not necessarily representative of other sampling populations.

   KEYWORDS: Anonymous respondent.

2. Azrin, N. H., W. Holz, and I. Goldiamond
   1961. Response bias in questionnaire reports. J. Consult. Psychol. 25(4): 324-326.

   To investigate the validity of an earlier study of military personnel concerning behavioral reactions indicative of fear in combat, the authors used two questionnaire forms on two groups of college students totaling 160 people. A response bias was found toward certain symptoms of combat fear regardless of whether or not the symptom was alleged to occur. Correlations between students and fliers were high. Probably the same type of response bias influenced the combat fliers. Unless objective and direct means of measurement are available, the questionnaire responses may be independent of the behavior being studied.

   EVALUATION: Good paper reminding researchers of bias involved if certain questionnaire answers are expected and the respondent learns of this expectation.

   KEYWORDS: Bias: nonresponse, stated vs. actual behavior.

3. Bachrack, Stanley D., and Harry M. Scoble
   1967. Mail questionnaire efficiency: controlled reduction of nonresponse. Publ. Opin. Quart. 31: 264-271.

   Contributors to the National Committee for an Effective Congress as of 1960 were sampled with a 25-page questionnaire yielding a 63.5-percent response rate. A two-page followup yielded an additional 19.5 percent. These procedures were used to reduce nonresponse: a prequestionnaire explanatory letter, a prestamped and addressed return envelope, and a post card for requesting report of findings. Followup letters repeated relevant information, and a second followup letter preceded the two-page questionnaire sent to all remaining nonrespondents. An identical form of this schedule was sent 1 month later, and the remaining nonrespondents were sent post cards containing 13 short, census-type data questions. Three major reasons are suggested that account for nonresponse: infirmities of advancing age, personal disturbances in individual's life style (job change or bereavement), and hostility toward

social survey research. Since a mailed questionnaire is an imposition, resistance is overcome by persuasion, persistence, attention to procedural techniques and details calculated to activate a potential respondent.

EVALUATION: Good, practical suggestions for increasing returns along with a case study example to support conclusions.

KEYWORDS: Followup: mail, post card
Incentive: postage
Cover letter.

4. Bain, Read
1931. Stability in questionnaire response. Am. J. Sociol. 37(3): 445-453.

A 61-item questionnaire given to 50 college freshmen was resubmitted to them 2-1/2 months later to measure the reliability of original results. One-fourth of the answers changed. Factual personal data changed less than factual family or subjective personal data. Girls changed their answers less often than boys.

EVALUATION: The small sample and the author's occasional overenthusiastic and unsupported statements reduce the value of this article. Appears slanted to support the author's point of view.

KEYWORDS: Reliability.

5. Ball, Robert Jaudon
1930. The correspondence method in follow-up studies of delinquent boys. J. Juvenile Res. 14: 107-113, illus.

A brief questionnaire was distributed to parents to determine their satisfaction with the behavior of recently paroled sons. Frequency of meaningful response appeared correlated with child's IQ, but parents gave favorable report when opposite was known to be true. Inferences about parents' intelligence were drawn from the manner in which the questionnaire was completed. Rate of return was extremely low (40-percent return with only 45 percent properly filled out).

EVALUATION: Dated, superficial, weak. It does alert researchers to the possibility of gaining information from the *manner* in which a questionnaire is completed.

KEYWORDS: Bias: nonresponse.

6. Barnette, W. Leslie, Jr.
1951. The non-respondent problem in questionnaire research. J. Appl. Psychol. 34(6): 397-398.

The solution to the nonresponse bias detection when a large nonrespondent group remains after two or three mail questionnaire followups is to randomly sample these nonrespondents and make persistent attempts to contact them. An example is given.

EVALUATION: Good example of persistence paying off in reducing nonresponse bias.

KEYWORDS: Bias: nonresponse
Followup: telephone, mail.

7. Bartholomew, Warren M.
1963. Questionnaires in recreation Their preparation and use. 12 p. New York: Natl. Recreation Assoc.

Results of a study by the National Recreation Association indicated that many questionnaires sent and received by recreation agencies are not effectively designed. Includes general comments on defining and clarifying the problem; types, content, wording, and sequence of questions; length of questionnaire; pretesting; distribution; ways to increase response; tabulation of data; and organization of the final reports.

EVALUATION: Superficial instruction on use of questionnaires with no references to other literature. Perhaps useful to beginners but dangerous if they proceed with this reference alone.

KEYWORDS: Questionnaire: design
Applications.

8. Barton, Allen H.
1958. Asking the embarrassing question. Publ. Opin. Quart. 22: 67-68, illus.

A humorous, short article consisting solely of eight ways to ask the embarrassing question, "Did you kill your wife?" in a nonembarrassing way. For example, the casual approach, the direct approach, a sealed ballot box, a projective technique, etc.

EVALUATION: Too brief with no discussion of important points.

KEYWORDS: Questionnaire: design
Question: wording.

9. Bauer, Rainald K., and Frank Meissner
1963. Structures of mail questionnaires: test of alternatives. Publ. Opin. Quart. 27: 306-311.

A test was made to determine the validity of the following rule of thumb: "A series of logically interdependent questions generate more meaningful answers if put on one page of the questionnaire." Of the 198 complete answers received to a one-page questionnaire, 53.5 percent were absolutely correct, 45.0 percent were conditionally correct, and 1.5 percent were absolute nonsense. Of the 765 complete answers received to a two-page questionnaire, only 47.0 percent were absolutely correct, while the proportion of nonsense answers increased to 5.0 percent. Therefore, not only did the proportion of absolutely correct answers decline when two pages were used

but nonresponse and nonsense answers increased. Test results were, therefore, consistent with the rule of thumb.

EVALUATION: Insufficient information is given to allow the reader to check conclusions, but findings do support other literature.

KEYWORDS: Questionnaire: design.

10. Baur, E. Jackson
1947. Response bias in a mail survey. Publ. Opin. Quart. 11: 594-600, illus.

The Veterans Administration mailed a questionnaire to 6,000 World War II veterans; 92 percent were returned. Characteristics of nonrespondents--interest in questionnaire topic, formal education, age, marital status, and parenthood--were analyzed. Nonresponse bias was highest from difference in interest in questionnaire topic. Forty-nine percent of the nonrespondents had not attained a high school education, whereas of the respondents, 30 percent were without high school education. Those who were married or had little education were slower to respond. Age and parenthood did not influence response. Nonrespondents were not the same as late respondents.

EVALUATION: Well-written, substantive article but a little weak in statistical analysis of results.

KEYWORDS: Bias: nonresponse.

11. Bender, Donald H.
1957. Colored stationery in direct-mail advertising. J. Appl. Psychol. 41(3): 161-164.

Navy and Air Force officers and enlisted men totaling 12,056 received variously colored questionnaires to determine if color would increase the response rates. Response rates for various combinations of color including white, blue, green, canary, pink, and goldenrod ranged from 6.4 to 11.6 percent. Mailings of colored questionnaires yielded higher returns as a group than white questionnaires, but the difference was statistically insignificant.

EVALUATION: This experiment is one of few which tests color, but the return rate was so low that results are totally unreliable.

KEYWORDS: Incentive: motivation
Questionnaire: format.

12. Bennett, E. M., R. L. Blomquist, and A. C. Goldstein
1954. Response stability in limited-response questioning. Publ. Opin. Quart. 18: 218-223.

Coefficients of stability were determined for 30 limited-response questions, for a 4-week, test-retest period, on 197 subjects. All stabilities were

significantly greater than could be expected by chance. The questions were classified into four general categories, and the mean coefficients of stability for these classes of questions ranged from 0.713 to 0.970. Theoretical implications and polling procedures are described in detail.

EVALUATION: Excellent discussion demonstrating problems of interpretation for fixed response—categories between informant and investigator.

KEYWORDS: Validity
Question: wording.

13. Benson, Lawrence E.
1946. Mail surveys can be valuable. Publ. Opin. Quart. 10: 234-241.

Six advantages and seven disadvantages of the mail questionnaire for use in public opinion research are discussed based on Gallup Poll experience. The two main disadvantages are difficulty of obtaining returns from a representative cross section of the population and the proportionately greater number of returns that come from strongly biased respondents. Often results of surveys need to be adjusted to account for predicted changes in voter behavior. Mail questionnaires can be valuable provided their limitations are known and their results properly understood and correctly interpreted. Actual survey problems are used as results, and extensive explanation is made of factors responsible for gross inaccuracies in the 1936 Literary Digest presidential poll.

EVALUATION: Excellent review of problems involved in the use of questionnaires with population samples, specifically for political surveys. Good treatment of nonresponse.

KEYWORDS: Advantages of questionnaires
Bias: nonresponse
Applications
Disadvantages of questionnaires.

14. Bevis, Joseph C.
1948. Economical incentive used for mail questionnaire. Publ. Opin. Quart. 12: 492-493.

During pretesting by Opinion Research Corporation, 10-, 25-, and 50-cent war stamps were distributed with a mail questionnaire. The 25- and 50-cent stamps resulted in roughly the same return rate, but the 10-cent stamp produced definitely lower returns. In the subsequent survey, only 25-cent war stamps were included. Of the 2,734 questionnaires, 84 percent were returned, with one followup. A number of the latter respondents also returned the stamp.

EVALUATION: Information missing on size of pretest samples and percentage returns. Difficult to say that economic incentive or patriotism resulted in greater returns.

KEYWORDS: Pretest
Incentive: money.

15. Blankenship, Albert B.
1940. The choice of words in poll questions. Sociol. & Soc. Res. 25 (Sept.-Oct.): 12-18.

Individual words can elicit emotions and prejudices from respondents. Words may confuse or imply other than what the investigator intended. If the investigator does use emotionally colored words, it should be clearly identified in his analysis just what was measured. Arrangement of words within phrases is important. Qualifying adjectives often provoke different responses to a question than when used without them. Author recommends a list of words to be avoided in questionnaires. Specific questions, clearly stated, are needed to avoid meaningless answers.

EVALUATION: Dated but useful article on word choice. Good references to available literature with some excellent, specific examples.

KEYWORDS: Question: wording.

16. _____
1943. Consumer and opinion research; the questionnaire technique. 238 p. New York: Harper & Bros. Publ.

This test includes topics on a historical perspective of questionnaires, the general technique of conducting a survey, formalizing the problem and study objectives, methods of collecting data, phrasing of questions, format of questionnaire, testing questionnaires for effectiveness, selecting sample, preparing and distributing materials, summarizing results, preparing the report, measuring the validity of surveys, and a case against the questionnaire survey technique.

EVALUATION: Text covers the range of problems encountered in questionnaire surveys. It should be supplemented with recent findings.

KEYWORDS: Textbook
History
Disadvantages of questionnaires.

17. Boek, Walter E., and James H. Lade
1963. A test of the usefulness of the post-card technique in a mail questionnaire study. Publ. Opin. Quart. 27: 303-306.

The post-card technique, a procedure that maintains anonymity but still allows followups with nonrespondents, was used to determine if 178 Health Department personnel would carry out their assigned functions in case of a nuclear attack. Replies were received from 86 percent of the

sample; after a followup letter, total returns were 99 percent. Post cards were an important factor in this high percentage of return, although the type of people surveyed and their relationship with the organization had some effect on the return.

EVALUATION: Rather superficial; response rate may have approached 99 percent without the post card due to nature of topic and official positions of subjects.

KEYWORDS: Anonymous respondent
Followup: post-card, mail.

18. Bradt, Kenneth
1955. The usefulness of a post card technique in a mail questionnaire study. Publ. Opin. Quart. 19: 218-222.

Questionnaires mailed to 5,356 dropouts of an armed forces correspondence course included a post card to be returned separately to provide a means of followup without destroying anonymity of the respondent. Slightly more than 4 percent of those who returned a questionnaire failed to return a post card. An 80-percent return was realized after one followup reminder. This post-card technique has broader application than is generally recognized.

EVALUATION: Good case study of the use of post cards to preserve respondent anonymity.

KEYWORDS: Anonymous respondent
Followup: mail.

19. Brennan, Robert D.
1958. Trading stamps as an incentive in mail surveys. J. Marketing 22(3): 306-307.

From a census tract with characteristics approximating the average of the market area, 456 households were selected at random. In a series of three experiments, half of the households were either sent or promised trading stamps or 25 cents, and half were given no incentives or had the length of their questionnaire reduced. The results of the three experiments indicate that small incentives do not increase the percent of mail returns significantly and that the additional cost does not warrant them. Such procedure merits consideration only if maximal information is desired.

EVALUATION: Study supported by fact that return rates were extremely low--22 to 29 percent.

KEYWORDS: Incentive: money, reward.

20. Britton, Joseph H., and Jean O. Britton
1951. Factors in the return of questionnaires mailed to older persons. J. Appl. Psychol. 35(1): 57-60.

One study of 328 retired Y. M. C. A. secretaries received 68-percent returns from a preliminary questionnaire about retirement and 51.9-percent returns from a longer one on the same subject. Followup letters to the 57 secretaries who had returned neither questionnaire resulted in a 50.8-percent return. Generally the same procedure was followed for a second study of 2,853 retired teachers. A 20-percent sample of nonrespondents was interviewed. Results show that the retired men in both studies had higher return rates. Former school administrators had higher returns than school teachers, and Y. M. C. A. secretaries with the highest returns were most apt to have served 25 years or more and to have moved more often since retirement.

EVALUATION: Case study examples not tied to any broader framework with which to generalize results and conclusions.

KEYWORDS: Questionnaire: length
Bias: nonresponse
Followup: mail.

21. Brooks, Vernon
1947. Can you trust mail questionnaires? Printers' Ink 86, 88, 90, 92, 96, 100.

Registered voters in New York City were selected in a market survey to determine if the respondents were a representative cross section of society. Their results showed that the respondents tended to be better educated, and to be in the upper income and professional and managerial occupation classes. The 20- to 29-year age group along with the 50-year-and-older group were underrepresented while the 30- to 49-year-old group was overrepresented. The authors conclude that if you are seeking opinions from a homogeneous group, mail questionnaires are fairly reliable, but if you seek opinions from a cross section of society, the mail survey is not reliable.

EVALUATION: This article points to some areas that the researcher should consider. The results may be questioned due to biasing effect of a voter registration sample being used as a representative cross section of people.

KEYWORDS: Bias: representativeness.

22. Brown, Morton L.
1965. Use of a postcard query in mail surveys. Publ. Opin. Quart. 29: 635-637.

A sample of 523 physicians was subdivided into two subsamples. The first received a two-page query consisting of a cover letter, two screening questions, and space for patient diagnosis. The second subsample received a cover letter and a return post card containing only the two screening questions. For the original mailing, the post-card form elicited a 15-percent greater response, but this difference disappeared at the conclusion of the second mailing. Only 5-percent fewer contacts were required for the post-card query group. Most significantly, the feasibility of the post-card query is questionable because only 80 percent of the physicians responded to the additional query sent following receipt of the post-card form. The post-card query procedure was considered less efficient than the alternate query for eliciting the type of data needed.

EVALUATION: That the initial post-card query may be less efficient than alternative forms is in part dependent upon the circumstances in a particular study. The method should not be ruled out based on the conclusion drawn in this paper.

KEYWORDS: Cover letter
Questionnaire: format.

23. Cahalan, Don
1951. Effectiveness of a mail questionnaire technique in the army. Publ. Opin. Quart. 15: 575-578.

A sample of 1,051 Army officers received a 23-page questionnaire dealing with Army interests. The cover letter stressed responsibility and requested a return within 5 days. Followup letters were not sent due to the 84-percent return rate. A large body of data available on each officer was used to check representativeness of return. The respondents did not vary significantly from the nonrespondents. The questionnaire technique produced efficient and representative sampling in a single mailing and was more anonymous, less expensive, and faster than the interview technique. The questionnaire technique should work well on any other group with fairly strong lines of institutional control or traditions of responsibility.

EVALUATION: The response rate might have differed if followup letters had been used. The report has little data but is worth reading in light of the use of "built-in" motivation for returning questionnaire.

KEYWORDS: Mail questionnaire vs. interview
Cover letter
Incentive: motivation.

24. Campbell, Donald T.
1950. The indirect assessment of social attitudes. Psychol. Bull. 47(1): 15-38.

Covered are four types of attitude assessment tests: (1) nondisguised structured: direct attitude test; (2) nondisguised-nonstructured: free response approach and essay; (3) disguised-nonstructured: "projective" techniques; and (4) disguised-structured: tests which approximate the objective testing of attitudes. There is no evidence that indirect tests obtain higher validity in measuring attitudes than do direct tests, but direct tests have much higher reliability than do indirect ones. Indirect tests have ability to pick up systematic, unconscious biases.

EVALUATION: Comprehensive review of the literature of the 1940's dealing with indirect assessment of attitudes.

KEYWORDS: Cover letter
Questionnaire: format
Validity
Mail questionnaire vs. interview
Attitudes.

25. Cannell, Charles, and Floyd Fowler
1963. Comparison of a self-enumerative procedure and a personal interview: a validity study. Publ. Opin. Quart. 27: 250-264.

Data of known validity from a sample of general hospitals were compared with data obtained from the responses of 462 persons in an interview procedure, and 465 persons in a self-enumerative procedure. Results show that when records are available or when reporting from respondents is done by proxy, the self enumerative procedure is more accurate. In contrast, diagnosis and type of surgery are reported more accurately in an interview. This is consistent with the common observation that interviews about episodes involving threatening or embarrassing surgery is better than in self-enumerative procedures. Education of the respondent was more important in the interview. But respondent motivation was found more important in self-enumerative procedure, which stresses the need for developing special motivational techniques if this procedure is employed.

EVALUATION: A well-written report tied directly to the data. Hypotheses are developed and tested, and conclusions consistent with the data are drawn.

KEYWORDS: Mail questionnaire vs. interview
Validity.

26. Cantril, Hadley
1940. Problems and techniques experiments in the wording of questions. Publ. Opin. Quart. 4: 330-332.

In a national survey of 3,100 persons, alternate wording of two questions was given. The first question read as follows, "Do you approve of Sumner Welles' visit to European capitals?" and its alternate read, "Do you approve of President Roosevelt's sending Sumner Welles to visit European capitals?" Response choices were: approve, disapprove, and no opinion. When Roosevelt's name was used, more people had opinions and although the percentage of people who approved the visit remained identical at 43 percent, more people disapproved when it was connected with Roosevelt. Response to the question without the President's name was 25 percent and response to the one with his name was 31 percent. This was more true of women than of men.

EVALUATION: One should gain an appreciation for the wording of questions by reading this article. The point to be made is, be extremely cautious in wording questions. For example, in the first question the respondent is asked about Sumner Welles' visit, and in the second question, about Roosevelt's decision.

KEYWORDS: Question: wording.

27. Cavan, Ruth Shonle
1933. The questionnaire in a sociological research project. Am. J. Sociol. 38(5): 721-727.

The reliability of an 80-item questionnaire was determined by retesting 123 eighth-grade children after a 1-week interval. The replies of 62 pairs of siblings were compared, and 29 mothers were interviewed to check on factual questions. Factual questions about parents were completely reliable in 92 percent of the cases; facts about the home, in 95 percent of the cases; and those involving estimates of numbers, time, etc., 62 percent. There was 38-percent disagreement in attitudinal questions, but half were minor. Concludes that questions involving attitudes or estimates have lower reliability than factual questions. Reliability is increased by avoiding fine detail.

EVALUATION: Valuable even though dated. Poorly written with some lack in design and slight inconsistencies in reporting.

KEYWORDS: Reliability
Attitudes.

28. Champion, Dean J., and Alan M. Sear
1969. Questionnaire response rate: a methodological analysis. Soc. Forces 47: 335-339.

A total sample of 2,290 people, from the city directories of Knoxville, Nashville, and Chattanooga, were mailed questionnaires resulting in 42-percent return after one followup. Special delivery postage yielded returns of 61.2 percent versus 41.9 percent for regular postage. Six-page and nine-page questionnaires were returned more often than three-page questionnaires. High and medium socioeconomic status (SES) persons responded more than low ones. Cover letters with an egoistic appeal (benefits the respondent would get from responding) resulted in greater response than letters with an altruistic appeal (benefits the research organization would get) from their response. Higher SES respondents favored altruistic-oriented cover letters, and lower SES respondents favored egoistic. 16 references.

EVALUATION: Informative study of response rate, clearly written with good literature review.

KEYWORDS: Incentive: postage
Cover letter.

29. Clausen, John A., and Robert N. Ford
1947. Controlling bias in mail questionnaires. Am. Statist. Assoc. J. 42(240): 497-511.

Nonresponse bias can be attacked on two fronts: (1) increase response and thus minimize unknown bias from nonrespondents and (2) estimate and correct for bias existing in nonresponding groups. Presents empirical data and literature review to spur returns. Concludes that a well-written cover letter plus followups can motivate response. Airmail and special delivery letters often help. Personalized greeting or signature do not. Interest in the questionnaire can be increased if questions of general or widespread interest are included. Estimating response bias may include consideration of respondent-nonrespondent homogeneity such as education or consistently different answers in successive waves of response after followups.

EVALUATION: Review of bias problems plaguing questionnaires but some too specific to be of general help.

KEYWORDS: Incentive: postage, motivation
Followup: mail, personal contact
Cover letter.

30. Colley, R. H.
1945. Don't look down your nose at mail questionnaires. Printers' Ink 210(March): 21, 104, 106, 108.

The mail questionnaire was once the principal tool in market research. Prior to World War II, however, the personal interview method became ingrained. War shortages of interviewers and transportation caused a reluctant return to the use of mail questionnaires. With careful planning, however, the questionnaire method is a valuable tool for consumer research. Problems of representativeness and respondent interest can be minimized if adequate safeguards are taken.

EVALUATION: Inadequate, popularized discussion of problems in mail questionnaires. Descriptions of procedures employed are incomplete.

KEYWORDS: Mail questionnaire vs. interview
History.

31. Corey, Stephen M.
1937. Signed versus unsigned attitude questionnaires. J. Educ. Psychol. 28(2): 144-148.

Study tested the belief that respondent-signed attitude tests are not as valid as those where respondent remains anonymous. An attitude scale containing 50 statements reflecting sympathy or antipathy toward classroom cheating was administered to 150 students, once with signatures required and once without. Both signed and unsigned tests had high split-half reliability coefficients with no significant differences between them. Correlation between scores on signed and unsigned tests was high (0.85 ± 0.02). Mean scores reflected a slight, but statistically insignificant, tendency for more sympathetic attitudes toward cheating to be expressed on anonymous papers, as did the total range in scores. The invalidating effects of signatures on questionnaires may be exaggerated.

EVALUATION: Concise article reporting a well-executed study.

KEYWORDS: Anonymous respondent.

32. Crutchfield, Richard S., and Donald A. Gordon
1947. Variations in respondents' interpretations of an opinion-poll question. Int. J. Opin. & Attitude Res. 1(3): 1-12.

One Gallup Poll question was studied using 114 interviews to determine respondent interpretation and to determine how these affected the results of the questionnaire. The results varied according to the frame of reference used by the respondent. Men responded differently from women. Questionnaire results may be misleading if the frame of reference is not carefully analyzed.

EVALUATION: Study clearly points to the need for careful question construction and cautious interpretation of the data in light of the respondent's interpretation of the questions.

KEYWORDS: Question: wording
Interpretation.

33. Cuber, John F., and John B. Gerberich
1946. A note on consistency in questionnaire responses. Am. Sociol. Rev. 11(Feb.): 13-15.

Three questionnaires were filled out by 132 sociology students at 2-week intervals. Questions were of a factual, attitudinal, or evaluative nature. Questions

were rearranged each time, and irrelevant questions inserted to disguise the purpose of the study. Seventy-two percent of the answers were consistent between applications. Factual questions showed the least reliability, differences in class levels or age of respondents were consistent. Questionnaire data should be accepted with caution until the methodological problems of reliability are investigated further.

EVALUATION: A note of caution against blind acceptance of questionnaire data. Contradicts other findings that factual questions are most reliable. Does not suggest guidelines to improve reliability or validity.

KEYWORDS: Reliability
Validity.

34. Davis, Robert A., and Edwin L. Barrow
1935. A critical study of the questionnaire in education. Educ. Admin. & Superv. 21(Feb.): 137-144.

Over a period of 38 years, 500 questionnaires used in educational studies were reviewed to determine the rate of return, types of response called for, techniques used to increase returns, reliability, validity, and source of respondent information (fact, opinion, memory). Authors found that reports of many studies omit vital information such as length and number of returns of questionnaires. Reliability and validity of most questionnaires are probably so low that results are inconclusive. More appropriate statistical techniques are needed to determine reliability and validity.

EVALUATION: Review article based on logical research criteria. Dated, but problems identified still exist.

KEYWORDS: Bias: nonresponse.

35. Deming, W. Edwards
1944. On errors in surveys. Am. Sociol. Rev. 9(4): 359-369.

Thirteen factors affecting the usefulness of surveys are: variability in response, differences between kinds and degrees of canvas, bias and variation arising from the interviewer, bias from sponsorship, imperfections in questionnaire design and tabulation plans, changes taking place prior to availability of tabulations, bias from late reports, bias from unrepresentative selection of respondents or the period covered, sampling errors and biases, processing errors, and errors in interpretation. Errors from some of these factors are larger than commonly supposed; research must find ways of reducing errors and survey limitations. There is a special responsibility in presenting data to describe all difficulties to reduce errors of interpretation and utilization. As knowledge about bias and variability increases, their effects can be taken into account systematically and surveys will be less hindered.

EVALUATION: Excellent paper summarizing major sources of error and their impact on survey research results.

KEYWORDS: Bias
Questionnaire: design
Interpretation.

36. Desing, Minerva F.

1941. Suggestions to the novice in the mechanics of research. Sch. Rev. 49(March): 206-212.

A list of suggestions is given to assist students, clerical help, and novices in gathering, organizing, and treating data to guard against ambiguities, inconsistencies, and other irritations impeding progress (and validity) of a questionnaire study. Twelve suggestions are given for gathering data and 23 relevant to coding, analysis, and clerical procedure.

EVALUATION: A good list of "how to do it" suggestions and precautions that would be vital to the novice and useful for the expert to review.

KEYWORDS: Questionnaire: design
Coding
Analysis.

37. Deutscher, Irwin

1956. Physicians' reactions to a mailed questionnaire: A study in "resistentialism." Publ. Opin. Quart. 20: 599-604.

A questionnaire headed "Public Images of Female Occupations," was mailed to a random sample of 379 male physicians. Returns were not received from 43 percent. The following social-psychological factors were isolated as potential reasons for nonresponse: resistance to demands to express stereotypes and broad generalizations; resistance to the limited alternatives presented in multiple-choice questions; resistance to value-laden, linguistic symbols such as "class"; and resistance to projective-type questions whose meaning and purpose are not clear to the potential respondent. The reduction of such forms of resistance would reduce nonresponse and incomplete returns.

EVALUATION: Excellent suggestions worth consideration.

KEYWORDS: Questionnaire: design
Bias: nonresponse.

38. ———

1966. Words and deeds: social science and social policy. Soc. Probl. 13(3): 235-254.

Social science conclusions are often based on verbal response to questions about attitudes and behaviors. But as early as 1934, evidence by LaPiere showed there may be no positive relationship between what people say and do, and there may be a high inverse relationship. However, both empirical evidence and theoretical rationale about this problem have been largely ignored. The social science model shows uncommon concern for methodological issues of reliability, neglecting problems of validity. A technology inappropriate to the understanding of human behavior has been developed. We do not know under what conditions a change in attitude anticipates a change in behavior and vice versa. Ideally, we should obtain information from the same population on verbal behavior and interaction on behavior under natural social conditions. The empirical evidence can best be summarized as reflecting wide variation in the relationships between attitudes and behaviors. Role theory can help us understand why man is constrained from acting as he "ought," and much can be learned from the undeveloped field of sociolinguistics.

What do we know about the attitudinal consequences of behavioral change? To polarize attention upon two variables labeled "attitude" and "behavior" is to continue down the wrong track. It is what goes on in between--the process--that needs attention.

EVALUATION: Lengthy but relevant discussion of an important problem in the interpretation and meaning of questionnaire data. Evidence given demonstrates differences between "what people say" and "what people do."

KEYWORDS: Validity
Interpretation
Bias: stated vs. actual behavior.

39. Diamond, Sigmund
1963. Some early uses of the questionnaire: views on education and immigration. Publ. Opin. Quart. 27: 528-542.

A selective historical review of the questionnaire. Earliest recording of the term in the English language is thought to be 1901. American dictionaries included it in the 1930's. Census, a form of the questionnaire research, is as old as government itself. In the 17th century, particularly in France, the questionnaire was used for studies of social and political phenomena. Horace Mann used questionnaires to both gather and make opinion about public school systems. One early questionnaire study sought to ascertain from slave owners information about religious instruction provided Negro slaves. The questionnaire was used to gather reasons for immigration. Many questionnaires reveal factors of interest to the respondents rather than to the originator.

EVALUATION: Interesting selection of historical examples but of limited applicability to questionnaires as a research tool.

KEYWORDS: History.

40. Dollard, John
1948-49. Under what conditions do opinions predict behavior? Publ. Opin. Quart. 12: 623-632.

Discussed are social and cultural factors which tend to sustain the validity of surveys and other factors which tend to make people's opinions unreliable for predicting their behavior. The following conditions may assist in understanding the relationship between opinion and action: (1) neurotics find it difficult to predict their behavior when their own serious conflicts are involved; (2) persons with poor verbal skills may find it difficult to forecast their own behavior; (3) people who habitually go into effective action after thinking things over can best predict their own actions; (4) the test situation should not be corrupted by extraneous threats or rewards; (5) a man can best predict future situations if he has experienced that situation before; (6) a man can predict a future situation, provided another experience does not change his mind first; and (7) a man can better predict what he will do in a future dilemma if he is told exactly what the dilemma will be.

EVALUATION: Excellent paper based upon psychological behavior theory that implicates the conditions of questionnaire validity.

KEYWORDS: Validity
Bias: stated vs. actual behavior.

41. Donald, Marjorie

1960. Implications of nonresponse for the interpretation of mail questionnaire data. Publ. Opin. Quart. 24: 99-114.

Extensive mail questionnaires to 2,768 dues-paying voluntary association members in 104 local units across the country yielded a 77.3-percent return using three followups. At least half the nonrespondents did not actually support the organization. A significant relationship was found between amount of effort needed to get response and member involvement. The higher the involvement, in terms of active participation, knowledge and understanding of the organization, and loyalty to it, the fewer stimuli required to induce a response. Nonresponse to specific questions was similarly related. A phone call appeared to induce a cognitive reorientation of nonrespondents who were as involved as those responding to the preceding stimulus except their participation followed a more passive pattern. Nonresponse implications for data interpretation appear especially severe for attitudinal items and future behavior. Implications were less pervasive for estimates of respondent's own current behavior and insignificant for estimates of general group behavior of others. In the latter case, although there was more variability in response with decrease in involvement, there were no significant differences among the pooled responses at different levels of involvement. Costs can be minimized by selecting a cutoff point where inferences can be made about remaining nonrespondents.

EVALUATION: "Significant" differences are reported in this paper. Questions that remain unanswered are how strong and important those differences are. Results in this paper are thus merely suggestive.

KEYWORDS: Bias: nonresponse
Incentive: motivation
Followup: mail, telephone.

42. Durant, Henry, and Irene Maas

1956. Who doesn't answer? Brit. Psychol. Soc. Bull. 29: 33-34.

Response is affected by the relationship between the subject of the inquiry and the recipient of the questionnaire. If it makes a difference who does not answer, then either the questionnaire technique should not be used or an attempt must be made to sample nonrespondents to see if they differ from respondents. In a test of university students, there were indications that people previously approached responded more readily a second time and that merely having to fill in two questions did not greatly increase cooperative response over having to fill in a 53-item questionnaire.

EVALUATION: Good advice. Also suggests that questionnaire length is not a major factor in nonresponse.

KEYWORDS: Questionnaire: length
Bias: nonresponse.

43. Eastman, R. O.

1945. Dangers in direct-mail surveys. Printers' Ink 210(Jan.): 36, 40.

Criticizes mail surveys and offers suggestions for improvement. Criticisms are: (1) mailed questionnaires automatically create two groups, the responsive

and the unresponsive and the resulting bias is difficult to determine; (2) data received are of insufficient depth to be useful for ascertaining anything other than strictly factual information. Suggestions are: (1) ascertain the distribution and characteristics of nonrespondents--it is not the number who respond that counts, but *who* responds; (2) don't cheat the data by slighting the analysis; few surveys are any good unless intelligently interpreted. Author concludes that the inexpensive characteristic of mail surveys is not an advantage, because one gets what he pays for.

EVALUATION: Popular and homey in style, but several good points about problems inherent in mail surveys.

KEYWORDS: Interpretation
Disadvantages.

44. Eckland, Bruce K.
1965. Effects of prodding to increase mail-back returns. J. Appl. Psychol. 49(3): 165-169.

The less accessible subjects in a survey sample often exhibit unusual characteristics which may be of interest to the researcher. When telephone and certified mail techniques were used to obtain a 94-percent mail-back return from 1,259 former college students, academic achievement variables were found to be related to the amount of prodding which was required to obtain a response. No significant relationship was found, however, between the amount of prodding and the veracity of the respondents' replies. Results indicate prodding may be warranted to determine effects of nonresponse.

EVALUATION: Well-written, concise report describing one method to reduce nonresponse bias.

KEYWORDS: Bias: nonresponse
Followup: mail, telephone.

45. Edgerton, Harold A., Steuart H. Britt, and Ralph D. Norman
1947. Objective differences among various types of respondents to mailed questionnaire. Am. Sociol. Rev. 12(4): 435-444, illus.

A followup study of all male contestants in the First Annual Science Talent Search using a mailed questionnaire revealed that: (1) "Winner" contestants make almost 100-percent returns of the questionnaire for each of 3 followup years, (2) "Honorable Mention" contestants make the next largest percentage of returns, and (3) "also ran" contestants have the lowest percentage of return. These results are consistent with previous studies which show that interest in the subject or sponsor influences returns. Analysis of Science Aptitude Examination scores of the "other" contestants for 4 followup years revealed that individuals replying faithfully to the questionnaire for 4 years tended to be superior on the examination. Their rising mean scores were directly related to frequency of replies, disregarding succession. Intensive and vigorous followup is a basic tenet in mail questionnaire research. Otherwise the tendency will be to obtain replies from those who have a special interest in the subject under study, or who exhibit some characteristics different from the nonrespondents or from the casual or indifferent respondents.

EVALUATION: Good example of a panel study on students.

KEYWORDS: Bias: nonresponse
Followup: mail.

46. Ellis, Albert

1946. The validity of personality questionnaires. Psychol. Bull. 43(5): 385-440.

This is a check of the validity of studies using questionnaires to distinguish neurotic from nonneurotic personalities. In each study reviewed, the results of personality assessment by questionnaire were compared with results obtained by other methods. Of 232 studies, 101 had correlation coefficients of r = 0.00-0.39. Of an additional 42 studies specifically checking whether respondents overrated themselves, 36 showed overrating. Author concludes that group-administered personality questionnaires are able to discriminate one time out of two between groups of adjusted and maladjusted individuals. There is little indication they can be used at all to diagnose individual cases. Lengthy bibliography included.

EVALUATION: An excellent and monumental review of validity of personality literature utilizing questionnaires. Bibliography, 360.

KEYWORDS: Validity
Literature review.

47. _____

1947. Questionnaire versus interview methods in the study of human love relationships. Am. Sociol. Rev. 12(Oct.): 541-553.

Empirical study involving a questionnaire as a followup 1 year after a structured interview was given on love relationships of college women. Conclusions are: (1) for studying these types of behavior, the questionnaire method is at least as satisfactory as interviews; and (2) as questions become more ego-involving, the questionnaire becomes better for producing relevant data. Does not rule out the interview as a method of providing depth or insight. Questionnaire is included.

EVALUATION: Author does not generalize to other research areas, but information seems useful in many other behavior research efforts.

KEYWORDS: Question: content
Mail questionnaire vs. interview.

48. _____

1948. Questionnaire versus interview methods in the study of human love relations. II. Uncategorized responses. Am. Sociol. Rev. 13: 61-65.

Part II of a study of 69 college girls interviewed on love and family relationships and surveyed 1 year later with an anonymous questionnaire to compare differences in uncategorized (open-end) responses, revealed more self-revelatory or unfavorable responses to the anonymous questionnaire than to the interview. However, probing during interviews increased such responses.

EVALUATION: Mean scores reveal small differences.

KEYWORDS: Mail questionnaire vs. interview
Closed-end vs. open-end questions
Anonymous respondent.

49. Ellis, Robert A., Calvin M. Endo, and J. Michael Armer
1970. The use of potential nonrespondents for studying nonresponse bias. Pac. Sociol. Rev. 13(2): 103-109.

Data obtained through study of 412 college students. Followup efforts of two questionnaires left 19 nonrespondents. Data indicate that late respondents do not provide a suitable basis for estimating the characteristics of nonrespondents. Attempts to distinguish between potential nonrespondents and late respondents indicate only the direction of nonresponse bias, not its magnitude. The researcher's main recourse is to extend the scope of the analysis beyond the self-report data and to gain information on subject characteristics from outside data sources. Although minor effects of nonresponse are evidenced on social background variables in this and other studies, it is possible that serious nonresponse error may be present among other variables.

EVALUATION: Excellent paper on nonresponse bias with 35 references for support.

KEYWORDS: Bias: nonresponse
Early vs. late response.

50. Erdos, Paul L.
1957a. How to get higher returns from your mail surveys. Printers' Ink 258(Feb.): 30-31.

The following 8 factors are important to securing a high percentage of returns: prestige of organization doing the survey, interest of respondents, readability and length of questionnaire, wording of letter and questionnaire to convince respondent of his importance to the survey, list of benefits to the recipient, assurance of respondent anonymity, offer of a report of results, stamped envelope for reply (airmail preferable).

EVALUATION: Excellent rules of thumb but lacking in criteria for evaluating effects of treatment.

KEYWORDS: Questionnaire format
Cover letter
Anonymous respondent
Incentive: motivation, postage.

51. _____
1957b. Successful mail surveys: high returns and how to get them. Printers' Ink 258(March): 56-60, illus.

If questionnaire return rates are low, then further mail survey techniques should include: post-card reminders, several mailings, telegrams, obligating respondent to participate in advance of receiving the questionnaire, or a premium. Premiums should attract the respondent, introduce no bias, and should be inexpensive and easy to mail. Three case histories are discussed. Premiums as a moneysaving device and the possibility of premium bias are discussed. Testing premium bias revealed a higher average income for premium-respondents than for nonpremium respondents.

EVALUATION: Excellent paper with good rules of thumb.

KEYWORDS: Incentive: reward
Followup: post-card, mail.

52. Ferber, Robert

1948a. The problem of bias in mail returns: a solution. Publ. Opin. Quart. 12: 669-676.

Returns are analyzed to determine, without using followups, whether a set of mail returns is, or is not, representative. Returns are grouped on the basis of their arrival time. If the distribution of item responses of the late respondents differs markedly from that of the early respondents, bias is presumed to exist, and followup interviews are necessary. Random order tests are not foolproof indicators of mail bias. Error may be inherent in the theory of probability on which these tests are based, and bias may be independent of the order of return due to certain nonmeasurable characteristics of the respondents. However, in most cases where bias is reflected in measurable characteristics, these tests do provide an objective means of testing for bias in mail surveys. Application of these bias tests to the pretest of a large scale survey would also be advantageous.

EVALUATION: Clues as to the representativeness of an incomplete sample *may* be obtained by assuming that late respondents resemble nonrespondents. This assumption cannot, however, be substantiated, and one is left to proceed on faith. A worthwhile paper--should be read. Also see Robert Ferber, 1950, Publ. Opin. Quart. 14: 193-197, and Publ. Opin. Quart. 13: 562-563, for further discussion of this paper in a letter to the editor. Also see Ford and Zeisel (1949).

KEYWORDS: Bias: nonresponse, representativeness
Early vs. late response.

53. _____

1948b. Which--mail questionnaires or personal interviews? Printers' Ink 222(7): 44-47, 61, 64-65, illus.

Advantages of the mail questionnaire compared with the personal interview include the following: a wider distribution of the sample, a smaller staff, lower cost, opportunity for frank responses, more ease in obtaining opinions of all family members, and easier access to high-income groups. Disadvantages include: nonresponse bias, low response rates from persons with low income and education, necessity of followups, little knowledge of causes and reasons for respondent's actions and attitudes, no assurance that the correct person responded, and length of time until replies are received. Each item is fully discussed, and the general conclusion is that neither the questionnaire nor the interview technique is superior. Conditions of the problem define the relative desirability of the two techniques.

EVALUATION: Well-balanced conclusions, good summary of questionnaire and interview use.

KEYWORDS: Mail questionnaire vs. interview
Advantages of questionnaires
Disadvantages of questionnaires.

54. _____

1966. Item nonresponse in a consumer survey. Publ. Opin. Quart. 30: 399-415.

A study of 14,600 usable questionnaires out of 40,000 mailed to subscribers of *Consumers Union* analyzed item nonresponse by characteristics of respondents and by type, position, and repetition of questions. One-third of the questionnaires contained two or more unanswered items, and one out of seven contained six or more items unanswered. Item nonresponse was higher for females, older people, and those in households where the main wage earner had only a grade school education or was retired or a housewife. Frequency of item nonresponse increased for questions requiring some thought or effort by respondents, but the pattern of item nonresponse by respondent characteristics was very similar for different types of questions. No relationship was found between frequency of item nonresponse and the position of the question on the questionnaire. Although the effect of item nonresponse on parameter estimates is not easily determined, item nonresponse can reduce substantially the reliability of estimates. In particular, if allowance is made for possible bias due to this source in estimates of the variances of parameters, the size of the standard errors may turn out to be substantially higher than without such adjustment.

EVALUATION: Validity of findings is questionable due to low rate of return.

KEYWORDS: Bias: nonresponse.

55. Ferriss, Abbott L.

1951. A note on stimulating response to questionnaires. Am. Sociol. Rev. 16(2): 247-249.

The effectiveness of three techniques for stimulating response to mailed questionnaires was tested in introductory sociology courses in the 11 Southeastern States. The use of a "deadline" stimulated an immediate, heavy response. By providing stamped addressed envelopes in the first and second waves of questionnaires, the flow of returns was increased. Postal cards as reminders were completely ineffective. Costs per return were slightly higher for the segment of the population which was not provided with stamped, return envelopes and which was not prodded. Responses were most frequently mailed on Thursday and Friday; least frequently, on Saturday and Sunday.

EVALUATION: Data support conclusions.

KEYWORDS: Incentive: motivation, postage
Followup: post-card.

56. _____

1963. Applications of recreation surveys. Publ. Opin. Quart. 27: 443-454.

Three types of recreation surveys and their use are discussed: travel studies from persons passing a transportation point; onsite studies from persons engaging in an activity under study; and household surveys from persons at home. Variables usually studied include: demography, trip characteristics (mode of travel, etc.), time and cost of trip, attitude and motivation of traveler, and decisionmaking factors. Several studies are summarized and their applications are discussed. Author suggests that more attitude, motivation, and decisionmaking factors be included to help explain additional variance.

EVALUATION: Although a moderately well-constructed typology of existing recreation surveys, includes nothing specific to the questionnaire method.

KEYWORDS: Applications.

57. Fischer, Robert P.
1946. Signed versus unsigned personal questionnaires. J. Appl. Psychol. 30: 220-225.

A psychological problem checklist was given to 102 female psychology students, first with and then without signatures being required. The interim between testings was 1 week. The results indicated that the mean number of problems listed as not serious did not vary significantly under the two conditions of administration, but that the mean number of serious problems listed tended to be significantly greater when signatures were not required. It would appear that the use of signatures on personal questionnaires might have an inhibitory effect on the honesty and frankness of the people responding to them.

EVALUATION: Good example of value of anonymity, especially for sensitive subjects under investigation.

KEYWORDS: Anonymous respondent.

58. Ford, Neil M.
1968. Questionnaire appearance and response rates in mail surveys. J. Adver. Res. 8(3): 43-45.

This mail survey to consumer shoppers tested printed cover letters against mimeographed cover letters to see if the printed ones would bring in a greater return than the mimeographed letters. Questionnaire and cover letters were sent to 1,556 consumers. The printed letter had a return of 22 percent, and the mimeographed letter had a return of 20 percent. Chi-square statistic showed no significant difference between them.

EVALUATION: The extremely low response rate would have made the results unreliable even if there had been a significant difference in returns between the two cover letters. This survey adds further evidence that no one variable is responsible for high return rates, but a combination of many is necessary.

KEYWORDS: Cover letter.

59. ———
1969. Consistency of responses in a mail survey. J. Adver. Res. 9(4): 31-33.

Questionnaires were mailed to 1,556 households. Of the 319 responding to the questionnaire on consumer shopping behavior, 159 were selected for interview to determine how consistently questions could be answered. Questions dealing with facts such as socio-economic factors elicited the highest degree of consistency. Attitudinal or opinion questions had the lowest average consistency between answers.

EVALUATION: One should gain an appreciation for the difficulty of using attitudinal and opinion questions from reading this paper.

KEYWORDS: Question: type, content
Reliability.

60. Ford, Robert N., and Hans Zeisel
1949. Bias in mail surveys cannot be controlled by one mailing. Publ. Opin. Quart. 13: 494-501.

Experimental data fail to show that a test for random order of response can detect bias after one mailing, as has been suggested by Ferber (1948a). The conclusion is that Ferber's statistical test is not sensitive enough to assure the analyst that a "no bias" finding indicates that no bias actually exists. The theory that late respondents to a single mailing are similar to the nonrespondents appears to have been offered by Ferber without support. The proposed procedure of analysis is dangerous in that it almost inevitably leads to a "no bias" verdict when bias can be shown to exist by the more difficult and costly techniques it seeks to avoid.

EVALUATION: Criticizes Ferber's 1948 paper: "The problem of bias in mail returns: a solution." Worth reading in conjunction with Ferber's paper.

KEYWORDS: Bias: nonresponse
Early vs. late response.

61. Frank, Benjamin
1935. Stability of questionnaire response. J. Abnorm. & Soc. Psychol. 30: 320-324.

The Bernreuter Personality Inventory was personally administered to 76 New Jersey prison inmates. Reliability coefficients (about 0.80) were smaller than reported by Bernreuter. Neutral items showed the highest index of change (average, 32.5 percent) with positive (yes) items and negative (no) items averaging about 21-percent change. Concludes that until the influence of situation and factors motivating response can be definitely stated, the personality questionnaire will remain a dubious clinical instrument.

EVALUATION: Dated study, with confusing presentation.

KEYWORDS: Reliability.

62. Franzen, Raymond, and Paul F. Lazarsfeld
1945. Mail questionnaire as a research problem. J. Psychol. 20: 293-320.

Although the main focus of this paper is on a study of who returns mail questionnaires, the authors also review several advantages and disadvantages of mail questionnaire use. Bias resulting from self-selection may or may not be significant and must be evaluated with regard to the topic of interest. The study reported in this paper compared personal interview replies from those who did respond with those who did not respond to a mail questionnaire to determine (1) the nature of any nonresponse bias which may occur, and (2) the bias which results from the two different methods of inquiry. It was found that consistent and statistically significant differences between respondents and nonrespondents were present. However, for practical purposes, the differences were either not large or could be corrected by weighting. Mail questionnaires have an advantage over interviews. For cultural subjects, they are more informative and show a freer admission of unusual activities or interests. On questions involving buying power, the mail response shows less reluctance to divulge information. An appendix is included in which interviewer bias (selection bias and opinion bias) is discussed.

EVALUATION: This paper takes a comprehensive look at several important problems associated with mail questionnaires and personal interviews. The study discussed is a good example of how problems of bias can be evaluated.

KEYWORDS: Bias: nonresponse
Mail questionnaire vs. interview
Reliability
Advantages of questionnaires
Disadvantages of questionnaires.

63. Frazier, George, and Kermit Bird
1958. Increasing the response of a mail questionnaire. J. Marketing 23(2): 186-187.

Two Idaho counties were chosen to test the effectiveness of adding a handwritten postscript which read, "P.S. We need your help in this report. Could you please send it in promptly?" There were 777 questionnaires sent out with the postscript included and 781 sent without the postscript. A chi-square test showed a 6.7-percent difference between them with 31.4 percent for letters with the postscript and 24.7-percent return for letters without.

EVALUATION: Poorly written paper, with some inaccurate reporting of findings. Data point to desirability of personalizing a questionnaire as much as possible.

KEYWORDS: Cover letter
Incentive: motivation.

64. Freeman, Linton C., and Türköz Ataöv
1960. Invalidity of indirect and direct measures of attitude toward cheating. J. Personality 28(4): 443-447.

The study was to determine the relationship between overt behavior and a direct question and three types of indirect attitude items to predict the behavior. Thirty-eight university freshmen and sophomores were ranked in terms of observed classroom cheating and polled with both direct and indirect items about cheating. All correlations were insignificant, and neither direct nor indirect questionnaire items were of any use in predicting behavior. These results thus cast doubt upon the validity of direct or indirect questions for the assessment of certain types of overt behavior.

EVALUATION: Good, interesting study demonstrating a major shortcoming of questionnaire research.

KEYWORDS: Validity
Disadvantages of questionnaires
Bias: stated vs. actual behavior.

65. Gannon, Martin J., Joseph C. Nothern, and Stephen J. Carroll, Jr.
1971. Characteristics of nonrespondents among workers. J. Appl. Psychol. 55(6): 586-588, illus.

Questionnaires were sent to 552 checkers in 14 food stores to identify their attitudes about supervisory practices, the social climate, and personnel policies in the firm. After a return of 63 percent, nonrespondents were compared with respondents on the basis of education, length of employment, marital status, sex, age, number of children, and supervisory rankings. A chi-squared analysis showed that nonrespondents were typically lower in education, of single status,

male, younger or older than the 30- to 49-year-old age group, and ranking in the bottom fifth of all employees. Length of employment and number of children were not found correlated with nonresponse.

EVALUATION: Brief paper presenting findings only. Discussion and implications of findings are lacking.

KEYWORDS: Bias: nonresponse.

66. Gee, Wilson

1950. The survey method, p. 300-329. *In* Social science research methods. New York: Appleton-Century-Crofts.

The mail questionnaire is introduced as a supplement to a more elaborate survey method. The chief advantages are its range, economy, and usefulness in social research for: supplementing a study, providing preliminary information necessary for a project outline, obtaining primary data, enlarging and supplementing the background of a problem, checking for changes, checking secondary data already available, and disclosing new problems. The serious disadvantages of the questionnaire are: the representativeness and accuracy of replies, and incomplete returns. A strong antagonism toward questionnaires has been created because too many are distributed, often indiscriminately. Preparer of the questionnaire should: carefully analyze and visualize the subject, request only information that respondents can furnish, avoid objectionable questions, impartially and clearly phrase questions, ask for information that can be easily furnished by the respondent, arrange questions in logical sequence, and use brevity that is consistent with a thorough treatment of the subject.

EVALUATION: Excellent reference worth consulting for an overall picture of questionnaire research.

KEYWORDS: Applications
History
Advantages
Questionnaire: design
Textbook.

67. Gerberich, John B.

1947. A study of the consistency of informant responses to questions in a questionnaire. J. Educ. Psychol. 38: 299-306.

Three forms of the same questionnaire were given to each of three groups which totaled 1,000 university students. The three forms were administered at different times and the results were: group A had 91.01 percent of answers consistent at 1-day intervals; group B, 76.08-percent at 7-day intervals; and group C, 73.72-percent at 10-day intervals. Answers to factual questions showed less consistency than either the adjustment or attitude types. Sex, age, and class rank were not significant factors. No informant had all answers consistent, but veterans were slightly more consistent than nonveterans, and students who graduated in the upper third of their class were more consistent than students who ranked in the lower third.

EVALUATION: Excellent paper on questionnaire validity.

KEYWORDS: Reliability
Validity
Attitudes.

68. Gerberich, J. B., and J. M. Mason
1948. Signed versus unsigned questionnaire. J. Educ. Res. 42(2): 122-126.

A 40-item questionnaire on academic background, plans, and study habits was given to 2,876 students taking a biological science course. Results were analyzed to determine the effect of signatures upon response. No significant differences were found between signed and unsigned questionnaires. Questionnaire included.

EVALUATION: Well-designed study; authors are careful not to overgeneralize conclusions.

KEYWORDS: Anonymous respondent.

69. Goldstein, Hyman, and Bernard H. Kroll
1957. Methods of increasing mail response. J. Marketing 22(1): 55-57.

A questionnaire survey of 4,716 general hospitals brought total returns from 99.7 percent of the hospitals. The original mailing of two copies of the questionnaire plus a return envelope brought a 68.1-percent return. The first and second followups plus a note on colored paper requesting cooperation had percentage returns of 63.6 and 56.3, respectively. The third followup using airmail and special delivery postage brought in a return of 72.8 percent. Although at least part of the high return was due to the methods employed, certain responses may have resulted from a sense of obligation to reply to governmental agencies' questionnaires.

EVALUATION: Case study example with no control over variables that had greatest and least influence over response rate.

KEYWORDS: Followup: mail
Incentive: postage, motivation.

70. Green, Bert
1954. Attitude measurement, p. 335-369. *In* Gardner Lindzey (ed.), Handbook of social psychology. Vol. I. Cambridge, Mass.: Addison-Wesley Publ. Co., Inc.

Chapter 9 deals with *scaling* instruments to measure attitudes. Questionnaires, attitudes, and scales are defined along with an evaluation of reliability, validity, and unidimensionality of scales. Most of the chapter is a highly technical discussion, with mathematical equations, of scaling methods.

EVALUATION: This chapter is most valuable for those developing or utilizing scales.

KEYWORDS: Reliability
Validity
Scaling
Textbook.

71. Gullahorn, John T., and Jeanne E. Gullahorn
1959. Increasing returns from non-respondents. Publ. Opin. Quart. 23: 119-121.

Former Fulbright and Smith-Mundt grantees in nine Midwestern States were

sent a prequestionnaire letter asking for post-card returns with their current address. Only 21 percent did not respond. A sample of 20 percent of these grantees, including both respondents and nonrespondents was interviewed; later all the grantees were sent a questionnaire with a business-reply envelope. Approximately 61 percent responded. A followup questionnaire brought an additional 18-percent response. Of the grantees who had responded to the prequestionnaire letter, 89 percent returned their questionnaires. Only 49 percent of those who had not acknowledged the first letter answered the questionnaire. Personal contact stimulated further cooperation since 95 percent of the grantees who had been interviewed were among the questionnaire respondents. After a second followup was sent, with half of the remaining nonrespondents receiving their followup letters by regular mail and half by special delivery, approximately half of the nonrespondents answered bringing the total questionnaire returns to 90 percent. A significantly greater proportion of the special delivery group (62 percent) than of the regular mail group (35 percent) responded to this followup. The use of a special delivery followup is worth the added expense, particularly in eliciting responses from individuals who have not acknowledged any previous correspondence. Among those grantees who had not previously responded, 60 percent of those whose questionnaires were mailed by special delivery answered, contrasted with 24 percent of those whose questionnaires were sent by regular mail.

EVALUATION: Good experimental evidence. Sample size not given.

KEYWORDS: Prequestionnaire letter
Incentive: postage
Followup: mail, personal contact.

72. Gullahorn, Jeanne E., and John T. Gullahorn
1963. An investigation of the effects of three factors on response to mail questionnaires. Publ. Opin. Quart. 27: 294-296.

While surveying former scholarship grantees, the authors investigated the effects of three factors on questionnaire response frequencies: the class of mailing, the color of the questionnaire, and the type of postage on the return envelope. By means of a 2 by 2 factorial design, the sample was randomly divided into eight treatment groups, each receiving a different combination of the three factors. First-class mailing elicited significantly higher returns than third-class (51 vs. 49 percent), but the color of the questionnaire was insignificant. Stamped return envelopes were significantly more effective than business-reply enclosures (52 vs. 48 percent).

EVALUATION: Very small but statistically significant results.

KEYWORDS: Incentive: postage, motivation.

73. Hamel, LaVerne, and Hans G. Reif
1952. Should attitude questionnaires be signed? Personnel Psychol. 5(2): 87-91, illus.

A total of 109 identified and 94 anonymous employee attitude questionnaires were obtained from department store employees. The questionnaire probed working conditions, supervision, coworkers, communication, company hours, pay, and type of work. Mean scores for the two groups did not differ significantly.

Results may have been influenced by the fact that questionnaires were administered by a university staff and respondents were assured that the questionnaires were for confidential research purposes only.

EVALUATION: In the absence of any mention about nonresponse, one wonders if nonresponse bias could affect results of this study.

KEYWORDS: Anonymous respondent.

74. Hancock, John W.

1940. An experimental study of four methods of measuring unit costs of obtaining attitude toward the retail store. J. Appl. Psychol. 24(Apr.): 213-230.

Four methods were used to determine attitudes toward independent stores versus chain stores. The cost per unit of usable returns for each method were: mail questionnaire with accompanying letter, $1.22; mail questionnaire with letter plus 25 cents, $0.79; mail questionnaire with letter and a promise that 25 cents would be mailed upon receipt of the questionnaire, $1.06; personal interview, $0.74. The questionnaire with 25 cents enclosed was the most satisfactory mail method with 47.2-percent usable returns. The questionnaire and letter only produced a response of 9.56 percent.

EVALUATION: Brief report of a Ph.D. dissertation. Conclusions support data.

KEYWORDS: Incentive: money
Mail questionnaire vs. interview
Cover letter.

75. Hansen, Morris H., and William N. Hurwitz

1946. The problem of non-response in sample surveys. Am. Statist. Assoc. J. 41: 517-529.

Mail questionnaires are low cost but may have high nonresponse, whereas interviews give complete response but have relatively high costs. By combining the advantages of each method, one can interview a sample of the nonrespondents of a questionnaire study. Given an estimate of the relative costs and the rate of response, one can compute the number of questionnaires necessary for a designated degree of reliability. With the actual rate of response, the number of interviews can then be adjusted to obtain this reliability. Appendix included with derivations for the statistical formulas.

EVALUATION: Extensive mail followup should precede interview. Bias might exist between mail questionnaire and interview such as evaluation apprehension in face-to-face contact.

KEYWORDS: Bias: nonresponse
Mail questionnaire vs. interview.

76. Hobson, Asher

1916. The use of the correspondence method in original research. Am. Statist. Assoc. J. 15(114): 210-218, illus.

A one-question letter is recommended for simplicity. If more questions are necessary, a one-page questionnaire is desirable over a more bulky presentation. Questionnaire results should be verified from other sources if possible.

Questions should interest recipients. Accompanying letters should be personal, with names of the addressees rather than a "Dear Sir" and signatures of the sender rather than a rubber stamp.

EVALUATION: A presentation of rules of thumb for mail questionnaire use which have changed little in light of recent quantitative evaluation of the same "rules."

KEYWORDS: Questionnaire: design
Incentive: motivation.

77. Hochstim, Joseph R., and Demetrios A. Athanasopoulos
1970. Personal follow-up in a mail survey: its contribution and its cost. Publ. Opin. Quart. 34: 69-81.

An area probability sample was drawn of Alameda County, California, which consisted of 8,083 persons for whom at least demographic and socioeconomic data were gathered by enumeration. A questionnaire was left at each household with a cover letter and return envelope. Returns were secured from 6,928 persons or 86 percent of the listed adults. Forty-two percent returned the questionnaire after the enumeration; 17 percent, after receiving a followup letter; 11 percent, after a telegram; 16 percent, when an interviewer called on them; and 14 percent did not respond. The nonrespondents were older and more likely to be retired, widowed; to live in a small household without children; to own their own home; to be white, male, and skilled. Minority groups were slightly overrepresented in the questionnaire returns due to their overrepresentation in the personal contact stage. Personal-contact followup tended to improve estimates associated with low socioeconomic status, and also resulted in some not-at-home bias resulting in a slight overrepresentation of women and large families. Extrapolation of the data could not be used to improve the estimates. People who reported no organizational membership or political activity, and people with low education, job insecurity, and no provision for medical care were less likely than others to respond by mail. The 5,630 mail responses cost about $6.55 each, and the 1,298 questionnaires secured by interviewers cost $13.65 each.

EVALUATION: Careful documentation of effect of various procedures in a large questionnaire study.

KEYWORDS: Followup: mail, personal contact
Cover letter
Bias: nonresponse.

78. Hoppe, Donald J.
1952. Certain factors found to improve mail survey returns. Proc. Iowa Acad. Sci. 59: 374-376.

Post cards sent to automobile owners of cars observed on the road at a given hour asked age, sex of driver, number of persons in car, and miles driven during the hour observed. Adding the sentence, "Please do not let your failure to return this card make it impossible for us to obtain a 100 percent return," increased response significantly to 64.3 percent. In a second post-card survey in Minnesota and Iowa, adding an identification number in invisible ink versus writing a case number disguised in the address made no significant difference in return rates.

EVALUATION: Study unclear as to the construct tested.

KEYWORDS: Questionnaire design
Bias: nonresponse
Incentive: motivation.

79. Hubbard, Alfred W.
1950. Phrasing questions. J. Marketing 15: 48-56.

A respondent's experience and purpose are integrated with his perceptions which necessarily change a factual answer to a question into a less objective "opinion." An unbiased opinion is never obtained; therefore, the researcher seeks the number of persons who do or do not have such biases and the degree of such biases. The bias should not be influenced or changed by the question itself. Awareness of this problem enables the question phraser to balance the implied favorable and unfavorable judgments against one another. For each question, three preliminary questions should be written and compared side by side. Then pretest several variations to determine bias and re-pretest any revisions. The reliability of alternative questions is discussed. For example, introducing a negative into the question increases suggestibility and decreases reliability. Many other rules and examples are given.

EVALUATION: This article should be read because it deals with seemingly minor but very technical differences in wording questions that are too often taken for granted.

KEYWORDS: Question: wording
Open-end questions
Reliability.

80. Hubbard, Frank W.
1939. Questionnaires. Rev. Educ. Res. 9(5): 502-507.

A review of five articles on questionnaire reliability, seven articles on validity, two on rate of return, and one on the use of illustrated questionnaires. Three trends and innovations include illustrated questionnaires, opinion-type questionnaires, and questionnaires asking the recipient if he will participate in a more detailed study.

EVALUATION: Dated but concise and well-organized review of questionnaire literature.

KEYWORDS: Reliability
Validity
Bias: nonresponse
Literature review.

81. _____
1942. Questionnaires, interviews, personality schedules. Rev. Educ. Res. 12(5): 534-541.

A general discussion of the literature appearing before 1942 which pertains to questionnaire wording, pretesting, sampling, followup, reliability, and use.

EVALUATION: Brief with little substantive content, but valuable as a bibliographic reference. Bibliography, 56.

KEYWORDS: Literature review
Mail questionnaire vs. interview.

82. Jahoda, Marie, Morton Deutsch, and Stuart W. Cook
1951. Data collection: the questionnaire and interview approach, p. 151-208. *In* Research methods in social relations with special reference to prejudice. New York: Dryden Press.

Chapter 6 includes questionnaires and interviews as sources of data, a comparison of the interview and questionnaire technique, types of question content, types of interviews and questionnaires, the sociometric method and pictorial techniques of data collection, questionnaires which form attitude scales, and the use of rating scales.

EVALUATION: Excellent reference.

KEYWORDS: Advantages of questionnaires
Bias: representativeness
Disadvantages of questionnaires
Open-end questions
Question: content, wording
Scaling
Textbook.

83. Jourard, Sidney, and Paul Lasakow
1958. Some factors in self-disclosure. J. Abnorm. & Soc. Psychol. 56(1): 91-98, illus.

A reliable questionnaire for the assessment of self-disclosure was used to test groups of both sexes, white and Negro, married and unmarried, for extent of self-disclosure of six different aspects of self to various target-persons: mother, father, male friend, female friend, female friend and spouse or both. The findings are summarized as follows: Young unmarried subjects, both white and Negro, showed the highest self-disclosure to mother. Subjects tended to vary the amount of self-disclosure with respect to the category of information to which an item about the self belonged. Two clusters of aspects emerged: a high disclosure cluster including attitudes and opinions, tastes and interests, and work; and a low disclosure cluster comprised of money, personality, and body. White subjects disclosed more than Negroes, and females more than males. There was significant interaction among groups of subjects, target-persons, and aspects of self. Married subjects disclosed less to mother, father, and same-sex friend than comparable unmarried subjects. Those who were married disclosed more to their spouses than to any other target-person. A significant correlation was found between parent-cathexis and self-disclosure to the parents. The more that the parents were liked, the more disclosures were made to them.

EVALUATION: Of only indirect interest to the use of questionnaires since focused on question of psychological concern. Identifies differences in self-disclosure that may have implications for questionnaire research.

KEYWORDS: Validity
Reliability
Bias: stated vs. actual behavior.

84. Katz, Daniel
1946. The interpretation of survey findings. J. Soc. Issues 2: 33-44.

Surveys should include: (1) explicitly stated assumptions, (2) research instrument designed on well-constructed hypotheses, (3) selection of an appropriate sample, (4) methods appropriate to study problems, and (5) determination of opinions you are sampling. Errors to be avoided are: (1) failure to ask related and dependent questions, (2) failure to determine respondent's frame of reference, (3) substitution of absolute value for percentage statistics, (4) quotation of a single respondent as "typical", (5) misuse of the "quota-control" method of sampling to control for the representativeness of subgroups.
EVALUATION: Good general discussion of possible pitfalls in interpreting survey research findings.
KEYWORDS: Validity
Questionnaire: design
Interpretation.

85. Kawash, Mary B., and Lawrence M. Aleamont
1971. Effect of personal signature on the initial rate of return of a mailed questionnaire. J. Appl. Psychol. 55(6): 589-592, illus.

A mail questionnaire was used to test if initial return rates would be higher for those receiving a personal signature on the cover letter than for a mimeographed facsimile. Three thousand students and ninety-one faculty members of the University of Illinois were asked about their use of and attitudes toward audiovisual instructional materials. No difference was found between those receiving the personal signature and those receiving the mimeographed one even when faculty were subdivided on rank (professor, associate professor, assistant professor, etc.).
EVALUATION: It is difficult to generalize findings to other studies because of uncontrolled variables operating in the nonresponse group. For example, no attempt was made to control for those who did not use the audiovisual facilities available, and therefore felt the questionnaire did not apply to them.
KEYWORDS: Bias: nonresponse
Cover letter.

86. Kelly, Robert Lincoln
1931. The revolt against questionable questionnaires. Assoc. Am. Coll. Bull. 17(3): 377-390.

Article proposes a plan by the Association of American Colleges for regulating the use of "poorly constructed and meaningless" questionnaires sent to college administrators. Outlined are questions asked about proposed questionnaires to determine if they should be answered. These include: Is the questionnaire adequately sponsored? Is its purpose stated? Is it a worthy educational topic? Can it be answered briefly? What guarantees are given that the information will be put to good use?
EVALUATION: Unlike the majority of antiquestionnaire articles of this era, the article offers questions that would be valuable to anyone constructing his own questionnaire.
KEYWORDS: Questionnaire: design
Disadvantages of questionnaires.

87. Kephart, William M., and Marvin Bressler
1958. Increasing the responses to mail questionnaires: a research study. Publ. Opin. Quart. 22: 123-132.

A questionnaire was sent to 100 nurses divided into 10 groups, but each group received different incentives to affect the return rate. These included a questionnaire only; a preview letter and then the questionnaire; a questionnaire plus a followup letter; a preview letter, questionnaire, and followup letter; questionnaire sent airmail; questionnaire sent special delivery; and questionnaire plus either a penny, nickel, dime, or quarter. Fifty-two percent returned the regular questionnaire, but the quarter incentive inspired a 70-percent return. The airmail delivery produced a 60-percent return; followup, 68-percent; and the special delivery, 66-percent. Other inducements had little effect. The inducements themselves may create a biased return. In view of the lower cost of followup procedures over money incentives, the former is the recommended procedure.

EVALUATION: Clear presentation of a large variety of inducements to increase mail returns. Worth reading before considering special incentives.

KEYWORDS: Prequestionnaire letter
Followup: mail
Incentive: money, postage.

88. Kivlin, Joseph E.
1965. Contributions to the study of mail-back bias. Rural Sociol. 30(3): 323-326.

Study based on 487 Pennsylvania farmers to determine effect on certain attributes of the rate of adoption of improved farm practices. Data show significant differences between respondents and nonrespondents. The nonrespondents adopted fewer practices, were older, had less education, and were less likely to belong to organizations. Perhaps more important than the differences is evidence that these differences may not seriously affect relationships among the variables being investigated. Mail-back bias appears broad and cuts across socioeconomic and research variables. The data also support the hypothesis that differences between early and late respondents tend to be indicative of differences between respondents and nonrespondents, but these can only be considered inferences.

EVALUATION: Paper worth consulting on the nonresponse issue.

KEYWORDS: Bias: nonresponse
Early vs. late response.

89. Knox, John B.
1951. Maximizing responses to mail questionnaires: a new technique. Publ. Opin. Quart. 15: 366-367.

Questionnaires were mailed to 173 unemployed Tennessee railroad firemen who were localized and suspicious of written communication which might adversely affect their chances of railroad reemployment. After 29.5 percent were returned, a followup letter and another copy of the questionnaire were sent. To further encourage replies, a turkey was offered to the lucky respondent whose number was

drawn. A postal authority stated that the practice used here was not a lottery and not illegal since the object was not financial profit. The response to this followup letter and prize offer was 18.8 percent.

EVALUATION: Very brief procedural account of a survey ignoring final results on the effectiveness of the technique, similar studies with conflicting results, nonresponse bias, etc. Of little value.

KEYWORDS: Incentive: reward
Followup: mail.

90. Knudsen, Dean D., Hallowell Pope, and Donald P. Irish
1967. Response differences to questions on sexual standards: an interview-questionnaire comparison. Publ. Opin. Quart. 31: 290-297.

Three different samples of white women, all of whom were or had been premaritally pregnant for the first time, were used. The first sample, 150 private patients of physicians, anonymously completed questionnaires in their physicians' offices. The second sample, 311 women selected from birth certificates, was interviewed confidentially. The third sample, 77 women in maternity homes, filled out questionnaires in the presence of an interviewer. Four similarly worded questions were asked of each sample. Data suggest that in interview situations respondent was more likely to support the public and restrictive sexual norms that she assumed were adhered to by the interviewer. Lower socioeconomic respondents deferred to the norms represented by the higher status interviewers. In the private and anonymous questionnaire situation, the respondents more often answered to subcultural norms. Therefore, compared with anonymous questionnaires, interviews may lessen the expression of deviance.

EVALUATION: Good experimental documentation of anonymity benefits of questionnaires.

KEYWORDS: Mail questionnaire vs. interview
Anonymous respondent.

91. LaPiere, Richard T.
1934. Attitudes vs. actions. Soc. Forces 13(2): 230-237.

Social attitudes are conditioned responses to social stimuli but, by derivation, are seldom more than verbal responses to symbolic situations. All measurement of attitudes by questionnaires proceeds on the assumption that there is a mechanical relationship between symbolic and nonsymbolic behavior. An unusual study indicated that this assumption is unreliable. While traveling with a foreign-born Chinese couple, the author and his companions purchased, in 251 instances, goods or services necessitating intimate human relationships. Only in one instance was service refused. It was concluded that quality and condition of clothing, etc., influenced the behavior of others toward the Chinese more than did race. After 6 months elapsed, the establishments patronized were surveyed by questionnaire. Thus, the overt reaction and the symbolic were both obtained. The questionnaires asked, "Will you accept members of the Chinese race as guests in your establishment?" Out of 128 replies, 92 percent of the restaurants and 91 percent of the hotels said "No." The remainder replied, "Uncertain, depends on circumstances." Only one "yes" was received. The author states that "social attitudes must be

derived from a study of humans behaving in actual social situations, not on the basis of questionnaire data." The questionnaire is cheap, easy, mechanical, and gives quantitative results. Human behavior study is time consuming, intellectually fatiguing, and dependent on the ability of the investigator. Its results are qualitative. Quantitative measurements are quantitatively accurate, qualitative evaluations are subject to human errors. Yet it would seem more worthwhile to make a shrewd guess regarding that which is essential than to accurately measure that which is likely to prove irrelevant.

EVALUATION: An interesting, empirical comparison of observations versus questionnaires that challenges the validity of questionnaire responses to predict behavior.

KEYWORDS: Advantages of questionnaires
Disadvantages of questionnaires
Validity
Bias: stated vs. actual behavior.

92. Larson, Richard F., and William R. Catton, Jr.
1959. Can the mail-back bias contribute to a study's validity? Am. Sociol. Rev. 24(2): 243-245.

Bias can have a "favorable" effect when selective returns are desired. An eight-page questionnaire, a stamped return envelope, cover letter, post card, and two followup letters were used in a study of 700 persons named on the mailing list of a national organization. A comparison of characteristics of early respondents to respondents of successive waves of followup and nonrespondents suggests that the latter group includes persons for whom the organization was not a significant reference group.

EVALUATION: Good systematic evidence on the nature of nonresponse bias.

KEYWORDS: Bias: nonresponse
Incentive: motivation
Followup: mail, telephone.

93. Lawson, Faith
1949. Varying group responses to postal questionnaires. Publ. Opin. Quart. 13: 114-116.

A sample of 950 persons in Great Britain was stratified by occupation and sent a questionnaire measuring attitudes toward gambling. In the 23-percent returns obtained, responding most frequently were psychologists, followed by secretaries, clergymen, lawyers, solicitors, trade union officials, musicians, members of Parliament, and bookmakers. Interest in gambling was considered the determining factor affecting response. Questionnaires from lawyers, bookmakers, and trade union officials were received mostly within the first week.

EVALUATION: The extremely low return rate makes conclusions questionable. Response did support contention that interest in questionnaire topic affects response.

KEYWORDS: Bias: nonresponse
Incentive: motivation.

94. Lazarsfeld, Paul F.
1940. The use of mail questionnaires to ascertain the relative popularity of network stations in family listening surveys. J. Appl. Psychol. 24(Spring): 802-816.

Direct interview and mail questionnaire methods for obtaining information are compared. Respondents to 669 mail questionnaires were later interviewed for the same information. Only minor differences were discovered in their response. Nonrespondents to the questionnaire had lower literacy and interest in the topic than respondents. The questionnaire is likely to be answered by the husband; the interview, by the wife.

EVALUATION: Logical article with empirical data on the use of questionnaires versus interviews, and nonresponse bias as a function of respondent interest and literacy.

KEYWORDS: Mail questionnaire vs. interview
Bias: nonresponse.

95. Lehman, Edward C., Jr.
1963. Tests of significance and partial returns to mail questionnaires. Rural Sociol. 28: 284-289, illus.

Observable differences between early and late respondents appears to provide the basis for approaching problems of nonresponse with regard to representativeness, sample probabilities, and the use of tests of significance. The technique suggests the nature of nonrespondents by indicating what effect they would have on the analysis had they responded. The method can provide qualitative information for general interpretation and can suggest differences between returns and nonresponses and their direction.

EVALUATION: Excellent article that should be consulted before analyzing data. The best the approach gives is a prediction of nonrespondent characteristics.

KEYWORDS: Bias: nonresponse
Early vs. late response.

96. Levine, Sol, and Gerald Gordon
1959. Maximizing returns on mail questionnaires. Publ. Opin. Quart. 22: 568-575.

Within 2-1/2 months of the mailing, 100-percent returns were obtained of two different questionnaires to each of 85 Blue Cross plans. A 90-minute questionnaire was sent to the enrollment director and a 20-minute questionnaire to the executive director of each plan. This article consists of suggestions to other researchers based on experience in the study; e.g., respondent preparation and involvement, questionnaire design and construction, and various followup procedures. A wealth of how-to-do-it questionnaire information is included, although the respondents in the study may have felt obliged to respond due to their official responsibilities rather than the author's expert technique.

EVALUATION: Good how-to-do-it information.

KEYWORDS: Questionnaire: design
Followup: telephone, mail
Incentive: motivation.

97. Lewin, Kurt

1951. Problems of research in social psychology, p. 163. *In* Field theory in social science. New York: Harper.

Discusses in one paragraph the use to which questionnaire data should be put by the researcher. Author suggests treating questionnaire answers not as an expression of fact but as reactions to a situation which are partly determined by the question and partly by the general situation of the respondent.

EVALUATION: Very brief statement of a perspective worth considering.

KEYWORDS: Interpretation
Textbook.

98. Lindsay, E. E.

1921. Questionnaires and follow-up letters. Pedagog. Seminary 28(3): 303-307, illus.

Two methods of timing followup letters were tested on 2,782 respondents: (1) plotting the returning questionnaires and sending out followups when the effects of the previous letter dropped and (2) sending followups soon after the original questionnaire and from then on at slightly increasing intervals. The first method resulted in 68-percent return and the second method in 92-percent return. Author concludes that questionnaire followup increases returns, with the second method the better of the two.

EVALUATION: Methodologically weak in that return rates are not comparable since the two followup techniques involved a different questionnaire and sampling universe. Nonetheless, the two methods are useful for timing followup letters.

KEYWORDS: Bias: nonresponse
Followup: mail.

99. Linn, Lawrence S.

1965. Verbal attitudes and overt behavior: a study of racial discrimination. Soc. Forces 43(3): 353-364, illus.

To measure the relationship between racial attitudes and overt behavior, subjects were asked to pose for a photograph with a Negro of the opposite sex. Discrepancies between verbal attitudes and subsequent behavior were found in 59 percent of the cases. The relationship between attitude (prejudice) and behavior (discrimination) is seen to be a function of the level of social involvement with the attitude object as well as the amount of prior experience with it. One implication of the study is that statements or predictions of racial behavior based on attitude measurements have little reliability unless first validated empirically.

EVALUATION: Long article also reviews several other studies showing discrepancy between questionnaire-measured attitudes and overt behavior.

KEYWORDS: Literature review
Disadvantages of questionnaires
Validity
Bias: stated vs. actual behavior.

100. Linsky, Arnold S.

1965. A factorial experiment in inducing responses to a mail questionnaire. Sociol. & Soc. Res. 49(2): 183-189.

Experimental study tested the contents of cover letters as they relate to response rate. Questionnaires were sent to 912 nurses; only the cover letters differed in the 16 different combinations of four variables: (1) handwritten personal salutation vs. "Dear member" and a mimeographed signature; (2) presence and absence of an explanation of the place and importance of respondent; (3) presence and absence of an argument for the social utility of the research; (4) presence and absence of an appeal to help the study researchers. Response rates significantly increased when a personalized letter and the place and importance of the respondent were included. Results showed that personalization and importance of the respondent brought higher returns (56.1 percent) than when all four factors were present (43.9 percent).

EVALUATION: Excellent study giving empirical evidence and 22 references.

KEYWORDS: Cover letter
Incentive: motivation.

101. Longworth, Donald S.
1953. Use of a mail questionnaire. Am. Sociol. Rev. 18(3): 310-313.

In each of a series of pretests, 50 randomly selected respondents answered an eight-page questionnaire. Placing small denomination stamps of various colors on the envelope increased returns by 2 percent. A personal note and typed letter of explanation on letterhead paper increased returns by 5 percent. When a newspaper clipping about the study was included, a further increase of 5 percent was noted. The followup phone call increased returns by 37 percent. In the study that followed the pretests, 800 questionnaires were distributed, and a total of 69 percent were returned.

EVALUATION: Good experimental evidence on effect of certain procedures on questionnaire returns.

KEYWORDS: Incentive: postage, motivation
Cover letter
Followup: telephone.

102. Lundberg, George A.
1929. Social research. Chapters 6 and 9. New York: Longmans, Green and Co.

These chapters discuss the value of systematic measurement through questionnaires, thoroughly describe their construction (size, shape, material, color, arrangement of items, wording), and make suggestions for getting accurate and wide response. Eight general types of questionnaires which can be used to measure attitudes are described and illustrated. Validity and the limitations of measurement in general are discussed.

EVALUATION: Although old, this book appears highly useful. Chapter 6 in particular might be consulted when designing a questionnaire study.

KEYWORDS: Questionnaire: design
Applications
Mail questionnaire vs. interview
Advantages of questionnaires
Validity
Disadvantages of questionnaires.

103. Macoby, E. A., and Nathan Macoby

1954. The interview: a tool of social science. Handbook of social psychology I: Theory and method. Reading, Mass.: Addison-Wesley.

This handbook deals explicitly with the methodology of interviewing but is directly applicable to mail questionnaires. Included are discussions on: when open-end questions are preferable to closed-end; how to word questions to promote understanding, accuracy, and conceptual validity; modifications and precautions necessary for cross cultural or linguistic settings; presentation of research findings on the validity of questionnaire versus interview data; four ways of judging the validity of the findings. Advantages and disadvantages of interviews and mail questionnaires, and when each is used best are included.

EVALUATION: Comprehensive, especially relevant where the choice of method is a concern.

KEYWORDS: Validity
Applications
Questionnaire: design
Mail questionnaire vs. interview
Textbook.

104. Magid, Frank N., Nicholas G. Fotion, and David Gold

1962. A mail-questionnaire adjunct to the interview. Publ. Opin. Quart. 26: 111-114.

The mail questionnaire can be used as an adjunct to the interview to shorten interview time without diminishing the volume of information. Nonresponse bias can be estimated from the distribution of related variables identified in the interview which characterize respondents and nonrespondents. Example of this is included. The rapport, interest, and commitment built up during the interview increase the probability of questionnaire response. Different interviewers successfully solicit different response rates to followup questioning. Other advantages include the provision of more anonymity and the possibility of making reliability checks to determine if differences between the individual interviewers can be explained by differences in the characteristics of their respondents.

EVALUATION: A descriptive how-to-do-it article by survey consultants.

KEYWORDS: Applications
Bias: nonresponse
Mail questionnaire vs. interview.

105. Manfield, Manuel N.

1948. A pattern of response to mail surveys. Publ. Opin. Quart. 12: 493-495.

The longer a recipient delays in answering, the less likelihood he will ever respond. Respondent interest in the topic of the questionnaire and his education level affect the rate of return but are of secondary importance. Veterans Administration questionnaires show roughly one-half of all returns to a particular mailing are received by the 3d day, three-fourths by the 5th day, and nine-tenths by the 10th day. Tabulation of returns should start the day the first batch of returns is received, and reports should include size of mailing,

number of returns, and description of sample.

EVALUATION: Superficial but illustrates rate and speed of questionnaire returns.

KEYWORDS: Bias: nonresponse.

106. Mason, Ward S., Robert J. Dressel, and Robert K. Bain
1961. An experimental study of factors affecting response to a mail survey of beginning teachers. Publ. Opin. Quart. 25: 296-299.

Differences in response rate were tested for combinations of a six-page, 62-item questionnaire; an eight-page, 92-item questionnaire; an address with respondent's name and code number; and an address with code number only. Four forms were randomly distributed to 741 teachers, and no significant differences in response were found. Neither placing the respondent's name and address directly on the questionnaire nor the use of a longer questionnaire influenced the results.

EVALUATION: Brief and to the point.

KEYWORDS: Questionnaire: length
Anonymous respondent
Bias: nonresponse.

107. Mayer, Charles S., and Robert W. Pratt, Jr.
1966. A note on nonresponse in a mail survey. Publ. Opin. Quart. 30: 637-646.

Data were collected as part of a study designed to explore the economic and psychological consequences of personal injury automobile accidents in Michigan. Returns were received from 2,137 of the 2,872 individuals (74 percent) receiving questionnaires. When nonrespondents were segmented into two categories, those who refused an interview and those who could not be located, each category produced a different, and sometimes offsetting, bias. Respondents who cannot be located tend to differ from respondents in that they are more often male, younger, and nonwhite, and they possess lower occupational skills. When these factors are combined, they represent a relatively mobile group in society. Analysis shows serious bias when that portion of the sample which has moved residence and does not receive a questionnaire is subtracted from the total sample size in order to show a higher percent return. If individual involvement in the survey subject underlies the motivation to respond, motivation provides a means of predicting the distribution of the characteristics of those who refuse. Biases introduced by nonrecipients of a questionnaire tend to coincide with characteristics of the mobile portion of the population being studied. As long as the relative size of nonresponse groups is known and the directions of bias can be evaluated through knowledge about the motivations of the "refusers" and the characteristics of the "mobiles," meaningful techniques can be developed to adjust for possible nonresponse bias.

EVALUATION: Excellent paper worth consulting before running an analysis.

KEYWORDS: Bias: nonresponse
Early vs. late response
Incentive: motivation.

108. Mayer, Edward N., Jr.

1946. Postage stamps *do* affect results of your mailing. Printers' Ink 217(Oct.): 91.

If all other factors are equal, the best return rate results from colored stamps in the following order: purple, blue, red, brown, green, and black. Newly issued stamps increase returns regardless of color. First class over third class mailing may or may not result in more returns.

EVALUATION: Weak. Lacks supporting data for the results presented. Business advertising is the probable source of facts.

KEYWORDS: Incentive: postage.

109. McDonagh, Edward C., and Leon A. Rosenblum

1965. A comparison of mailed questionnaires and subsequent structured interviews. Publ. Opin. Quart. 29: 131-136.

Questionnaires were mailed to 2,497 randomly selected residents listed in a California city directory. Interviews were conducted on a 10-percent subsample of the 1,117 respondents and the 1,262 nonrespondents. The data show no statistically significant differences between the mailed questionnaire and the structured interview. The mailed questionnaire revealed representative responses in spite of the partial return.

EVALUATION: Important methodological study suggesting choice of data gathering technique can be based on the type of information desired rather than representativeness of results.

KEYWORDS: Bias: nonresponse
Mail questionnaire vs. interview.

110. McNemar, Quinn

1946. Opinion--attitude methodology. Psychol. Bull. 43(4): 289-374.

A critical appraisal of major methodological problems involved in study of opinions and attitudes. Topics include problems and issues, attitudes by scaling techniques, single-question opinion gaging, administration, statistical issues, study of changes, correlates and interrelationships, and studies of morale. Stresses need for greater reliability, validity, and unidimensionality of opinion- and attitude-measuring instruments. Questions the dependability of single-question measures and recommends the use of attitude scales to attain satisfactory reliability. Unitary scales can be developed using Guttman scaling technique. Validity can be established, but not without more effort than is usually expended. Study of attitude change might be conducted under experimental conditions with control groups and study of attitude and opinion correlates, but greater stress on formulation of hypothesis is needed.

EVALUATION: Dated, but a definitive "state of the art" work in opinion and attitude measurement with excellent literature review (133 citations).

KEYWORDS: Reliability
Validity
Literature review
Attitudes
Scaling.

111. Metzner, Charles A.
1950. An application of scaling to questionnaire construction. Am. Statist. Assoc. J. 45(249): 112-118, illus.

The best form of a question on the price World War II veterans would pay for housing was determined by Thurston scaling. Semantically different questions were submitted to 100 people who judged the meaning of the questions. The question most central to the scale presumably had the least bias. The undesirable semantic effects of words or phrases were negated in the questionnaire to the veterans.

EVALUATION: A good example of the possibilities which scaling techniques can offer for question construction.

KEYWORDS: Questionnaire: design
Scaling
Question: wording.

112. Metzner, Helen, and Floyd Mann
1952. A limited comparison of two methods of data collection: The fixed alternative questionnaire and the open-ended interview. Am. Sociol. Rev. 17(4): 486-491.

About 800 company employees filled out fixed alternative questionnaires and were interviewed to determine if differences existed between the two data collecting methods on personal and background characteristics and feelings about their jobs. Respondents indicated more positive attitudes toward their jobs on interviews than on questionnaires. The degree of confidence in anonymity and degree of satisfaction with job might account for the differences.

EVALUATION: Well-written article relevant to selecting a research instrument for measurement of attitudes.

KEYWORDS: Mail questionnaire vs. interview
Bias: stated vs. actual behavior
Anonymous respondent.

113. Mitchell, Walter, Jr.
1939. Factors affecting the rate of return on mailed questionnaires. Am. Statist. Assoc. J. 34(208): 683-692, illus.

Seven factors affect the rate of returns: selectivity of the mailing list, timeliness, prestige of the sending agency, salesmanship in the cover letter, reluctance of respondents to identify confidential figures, respondents' stake in the success of the survey, and time in filling out the questionnaire. Forty-three surveys are plotted to show how time burden affects the percent return. Best returns are obtained when questionnaires are brief, on a current interest topic, sponsored by a prestigious organization, and sent to large enterprises who have previously cooperated.

EVALUATION: Good attempt to quantify factors related to rate of return.

KEYWORDS: Incentive: motivation
Bias: nonresponse
Questionnaire: format.

114. Moore, Clarence Carl

1941. Increasing the returns from questionnaires. J. Educ. Res. 35(2): 138-141.

Questionnaires were sent to 494 school superintendents. Of the accompanying letters, 238 were individually typewritten and 256 were duplicated. A duplicated followup letter was sent 8 weeks later. Eighty-two percent of the typewritten sample responded whereas 66 percent of the duplicated letter group responded. Conclusion is that typewritten letter accounted for 16-percent increase in number of questionnaires received. Followup is also effective in increasing response.

EVALUATION: The followup should have been typewritten or duplicated to be consistent with the original mailing. Quality of the duplication may greatly affect results also.

KEYWORDS: Followup: mail
Incentive: motivation.

115. Morgan, Roy

1949. Follow-up letters disclose trends following opinion surveys. Publ. Opin. Quart. 13: 686-688.

Australian public opinion polls commonly send followup letters to people interviewed in regular opinion surveys to check the performance of interviewers and to reveal shifts in opinion which take place after a survey. The letters reproduce the answers which respondents gave a month previously and ask respondents to indicate the cases in which their opinions have changed. Business reply envelopes are enclosed, and returns average between 50 and 55 percent of all letters sent out. In general, respondent opinions on most subjects are stable, but there is a uniform decrease in the "undecided" or "no opinion" categories for mail surveys. This latter effect suggests that mail surveys make respondents think about current problems.

EVALUATION: Poor mail return leaves half the sample out of the analysis.

KEYWORDS: Applications
Mail questionnaire vs. interview
Followup: mail.

116. National Education Association

1930. The questionnaire. Res. Bull. Natl. Educ. Assoc. 8(1): 1-51, illus.

Contains reasons for and against questionnaire use, ways to prepare better questionnaires, ways to report questionnaire results, a proposed plan for the cooperative regulation of questionnaires, and 33 references.

EVALUATION: Useful "handbook" for questionnaire research even though it is compiled for school administrators.

KEYWORDS: History
Disadvantages of questionnaires
Advantages of questionnaires
Literature review
Questionnaire: design, format.

117. Nichols, Robert C., and Mary Alice Meyer
1966. Timing postcard follow-ups in mail-questionnaire surveys. Publ. Opin. Quart. 30: 306-307.

A 12-page questionnaire was sent to 1,600 college students. Half received a followup post card 3 days after the questionnaire was mailed; the other half did not. An additional followup post card was sent to half of each group after 16 days and to the other half 27 days after the questionnaire was mailed. After 45 days, a second copy of the questionnaire was sent to all remaining nonrespondents. At 120 days, the response rate was significantly higher for the 3-day post-card group. After 45 days, there were no significant differences in response rate between the 16-day followup and the 27-day followup. The best response rate was a combination of 3-day and 27-day followups which by the 27th day produced a 77- to 51-percent advantage over the group that received no followup.

EVALUATION: Excellent reference pointing to the need for followup reminders.

KEYWORDS: Followup: mail
Incentive: postage.

118. Nixon, John E.
1954. The mechanics of questionnaire construction. J. Educ. Res. 47(7): 481-487.

Presents a series of practical suggestions for constructing and developing the physical form and for final publication of a questionnaire. Emphasis is placed on consideration for the respondent, since the objective is to obtain as many responses as possible. Questionnaire forms that meet criteria of physical attractiveness and consideration, including materials, arrangement, directions, cover letter, envelopes, mailing, and followup technique, should receive the percentage of replies sufficient to fulfill the investigator's requirements.

EVALUATION: Well-organized outline for questionnaire construction.

KEYWORDS: Questionnaire: design.

119. Norman, Ralph D.
1948. A review of some problems related to the mail questionnaire technique. Educ. & Psychol. Meas. 7(2): 235-247.

A literature review of 37 references concentrated between 1930-48 shows that: followups increase the percentage of returns, rewards should be used with caution, the questionnaire format is important, the study sponsor's identity is important, best time to issue a questionnaire is early in the week and early in the school year, and too long a questionnaire may reduce returns. Respondents differ from nonrespondents in interest toward the questionnaire. Late respondents may differ from early respondents.

EVALUATION: Good general summary supported by several tables illustrating comparisons.

KEYWORDS: Literature review
Bias: nonresponse
Followup: mail
Questionnaire: format
Early vs. late response
Incentive: reward, motivation.

120. Olson, Williard C.

1936. The waiver of signature in personal reports. J. Appl. Psychol. 20(4): 443-450.

The Woodworth-Mathews Personal Data Sheet, a personality test to measure emotional instability, was given to two comparable groups of college women, one group remaining anonymous, the other group signing their names. The test was then given a second time with instructions reversed. In the initial application, subjects reported significantly more feelings and symptoms with neurotic implications under anonymous conditions than when required to sign their names. However, the initial test appeared to establish a set, or memory factor, preventing large changes on the second application to the same group.

EVALUATION: Substantial evidence of questionnaire bias on very personal data with secondary evidence of memory restricting much change on the same questionnaire. Well written but confusing presentation of quantitative data.

KEYWORDS: Anonymous respondent.

121. Oppenheim, A. N.

1966. Questionnaire design and attitude measurement. 298 p., illus. New York: Basic Books.

A comprehensive text on all phases of questionnaire use. Discusses problems associated with the several approaches to survey and questionnaire research. Questionnaire construction chapters deal with question wording, attitudes and attitude scaling, use of projective techniques, and others. Analysis section deals with data coding, preparation of cards for computer analysis, and table analysis. Appendix lists established socioeconomic rankings for approximately 500 occupational categories.

EVALUATION: Excellent, comprehensive, up-to-date, readable references.

KEYWORDS: Analysis
Question wording
Reliability
Advantages and disadvantages of questionnaires
Questionnaire: design
Attitudes
Textbook.

122. Pace, Robert C.

1939. Factors influencing questionnaire returns from former university students. J. Appl. Psychol. 23(3): 388-397.

A 52-page questionnaire was sent to 1,507 former University of Minnesota students to determine characteristics and activities since leaving school. With 69-percent return, the study results show that the method of comparing early versus late returns is not as sensitive to the true extent of bias as is the direct comparison of returns versus nonreturns, but this former comparison does indicate direction of bias. University graduation and number of years of school completed were important factors influencing returns, but sex, age, and year of entrance to the university were unimportant.

EVALUATION: Good study worth reading.

KEYWORDS: Bias: nonresponse
Early vs. late response.

123. Parry, Hugh J., and Helen M. Crossley
1950. Validity of responses to survey questions. Publ. Opin. Quart. 14: 61-80.

The article examines two concepts of validity (as a test to predict performance and as a matter of interpretation or definition), reviews the literature on the subject, and presents results of a specially designed survey in Denver which showed that the validity of even simple "factual" responses may often be open to question. Invalidity was shown to commonly follow social pressures; with more respondents exaggerating their participation in elections than underreporting it. The same tendency was noted in the report of possession of library cards and driver's licenses.

EVALUATION: Excellent discussion on questionnaire validity both for philosophical reasons and for practical reasons.

KEYWORDS: Validity
Literature review.

124. Parten, Mildred
1950. Surveys, polls, and samples: practical procedures. 624 p., illus. New York: Harper and Brothers.

Presents information on procedures used by population surveyors and on evaluations of populations by questionnaires and related devices. Includes the historical background of population surveying and a description of significant current practices. Presented is a guide for planning the survey, drafting the forms, writing the instructions, securing the information, and interpreting and reporting the results. Particular emphasis is given to the problem of bias and to specific procedures which meet technical problems arising at each stage of the survey operation. Primary consideration is given to surveys that gather information about people rather than about the agencies or facilities provided for them.

EVALUATION: Good reference text especially on historical aspects. Includes 1,145-reference bibliography.

KEYWORDS: History
Questionnaire: design
Bias: nonresponse, representativeness, stated vs. actual behavior
Analysis
Textbook.

125. Payne, Stanley L.
1950a. Case study in question complexity. Publ. Opin. Quart. 13: 653-658.

This article examines 16 questions given in a national survey of 6,400 people. Each of the questions contains an alternative question such as, "Do you think that this tax is about right, or is it too high?" Half the questionnaire had the alternative in the question reversed such as, "Do you think that this tax is about right,

or is it too low?" Nine of the questions proved to be "tight," in that differences in answers between the two forms did not exceed 2 percent. Seven questions, labeled as "loose," produced statistically significant different answers ranging from 4.5 percent to 7.5 percent. Results show that the loose question's alternative was selected more often when it was presented last, opinions were held less strongly on the tight questions than on the loose ones, and question brevity and simplicity are important elements of "tightness." Flesch Readability Scores revealed that the tight questions qualified as suitable for people who had completed seventh or eighth grade, and the seven loose questions qualified as difficult or suited for people of high school or more education.

EVALUATION: This paper is addressed to interviewers but the generalities apply to mail surveys.

KEYWORDS: Question: wording.

126. _____

1950b. Thoughts about meaningless questions. Publ. Opin. Quart. 14: 687-696.

Researchers should understand that respondents will answer questions that may be meaningless to them and that answers are not always random depending upon the respondents' predisposition. The proportion of respondents for whom questions are meaningless is impossible to determine and the fact that answers fit subsequent behavior does not prove that questions were meaningful. Even consistency of replies is no proof that a question is full of meaning. Precautions against meaningless questions include recognizing issues or terms that could be meaningless to many respondents, avoiding abstractions or words with vague and general definitions, avoiding long and complicated questions or words, using "filter" question to determine if respondent understands question or issue, using scaling techniques which will eliminate questions that do not "scale" with others on the same topic, and pretesting questions before they are used extensively.

EVALUATION: Excellent suggestions, clear and well presented with examples to support contentions.

KEYWORDS: Question: wording.

127. _____

1951. The art of asking questions. 249 p. Princeton, N.J.: Princeton Univ. Press.

Major topics covered include the importance of asking good questions; a description of the open-end question and its demerits; a discussion of the two-way question and its duplicities; a discourse on the multiple-choice question and its misconstructions; a description of special types of questions and their faults; the concern for respondents' privacy; the virtues of brevity and simplicity; problems with individual words and questions; a short lesson on punctuation, phonetics, and abbreviations; a checklist of 100 considerations; and 53 references.

EVALUATION: Clearly presented text on a subject deserving greater appreciation.

KEYWORDS: Question: content, type, wording
Textbook.

128. Pedersen, Darhl M., and Vincent J. Breglio
1968. The correlation of two self-disclosure inventories with actual self-disclosure: a validity study. J. Psychol. 68: 291-298.

Two self-disclosure measures and a self-disclosure questionnaire were administered to 52 subjects. Each of the self-disclosure measures yielded four scores which indicated the extent to which the subjects claimed they had disclosed information about themselves to four target persons (mother, father, best male friend, and best female friend). The questionnaire yielded separate scores of actual depth of self-disclosure in five topic areas (interest, personality, studies, body, and money), a total depth of disclosure score, and a total amount of disclosure score. Correlations between the 10 scores and the seven questionnaire scores indicated that total depth of disclosure was highly correlated with total amount of disclosure; that both total depth and total amount of disclosure were correlated with mother and father; that the only area of actual disclosure consistently related to claimed disclosure was that of studies.

EVALUATION: Worth reading if interested in overt versus verbal disclosed behavior.

KEYWORDS: Bias: stated vs. actual behavior.

129. Perry, Harold E.
1925. The questionnaire method. J. Appl. Sociol. 10(Sept.-Dec.): 155-158.

Responses to two questionnaires completed by junior high teachers were rejected because the investigator "knew," from 2-year association with the subjects, that their true attitudes were not revealed. Reasons why the questionnaire method is good for objective data but inaccurate for subjective data are given: (1) it is impersonal and fails to arouse emotions which reveal attitudes; (2) it allows variation in interpretation of questions; (3) questions are often answered to give certain impressions; (4) it encourages brief, concise answers which do not portray attitudes; (5) questions are often too direct and arouse antagonism or inhibition.

EVALUATION: Dated, essay-style article based on intuition and vague experience rather than data.

KEYWORDS: Advantages of questionnaires
Disadvantages of questionnaires.

130. Perry, Reginald
1923. Putting persuasive power into a questionnaire. Printers' Ink Vol. 123, May 10, p. 125-129.

Essay about using questionnaires to gather ideas for equipment advertising from superintendents of plants. Advises readers to leave plenty of white space between questions. Avoid "yes" or "no" questions since they will not provide new ideas. Write questionnaires in conversational style. Dovetail questions with one another to insure adequate information.

EVALUATION: Dated, weak essay of no value for research purposes.

KEYWORDS: Questionnaire: design.

131. Phillips, Marjorie

1941. Problems of questionnaire investigation. Res. Quart. 12: 528-537.

Seven disadvantages and three advantages of questionnaires are given. Nine items are given to consider before constructing a questionnaire, and 15 desirable practices are given for its construction. Ten questions are then offered as criteria for judging a questionnaire already constructed. A questionnaire is a cooperative effort between the individual constructing it and the respondents who should thus be treated with all possible consideration. Lengthy bibliography of questionnaire use in education included.

EVALUATION: Good general advice but some of it outdated and specific to education.

KEYWORDS: Disadvantages of questionnaires
Advantages of questionnaires
Questionnaire: design.

132. Phillips, William M., Jr.

1951. Weaknesses of the mail questionnaire: a methodological study. Sociol. & Soc. Res. 35(3): 260-267.

To ascertain the extent of investigator control over representativeness of response, the author obtained data from a sample of 93 Fisk University graduates. By the use of followups, response was increased approximately 50 percent; by the use of personalizing devices (postage and personal letter), response was increased approximately 70 percent. No significant differences were found between early, late, and nonrespondents when the four factors of year of graduation, sex, marital status, and number of children were tested. It was concluded that the investigator can control the representativeness of his sample by increasing response to a mailed questionnaire through use of followup and personalized devices.

EVALUATION: Paper falls short of expectations aroused by title, but it does offer further evidence of the value of followups to questionnaire studies.

KEYWORDS: Bias: nonresponse
Followup: mail
Farly vs. late response
Incentive: motivation, postage.

133. Plog, Stanley C.

1963. Explanations for a high return rate on a mail questionnaire. Publ. Opin. Quart. 27: 297-298.

The return rate for 162 questionnaires mailed to readers who had sent letters to the editor was 92 percent for one sample and 98 percent in a second. Factors affecting the return rate were respondent interest, mailing of questionnaires the same day that letters were received, enclosure of individually typed letters of explanation and postage-free, addressed return envelopes.

EVALUATION: Results have limited application and were based upon speculation.

KEYWORDS: Incentive: motivation, postage
Cover letter.

134. Price, D. O.
1950. On the use of stamped return envelopes with mail questionnaires. Am. Sociol. Rev. 15(5): 672-673.

All 157 members of a regional sociological society were sent invitations to join a national sociological society. Half of the return envelopes were postage paid; the other half were not. After 6 months, 23.3 percent of those receiving stamped return envelopes and 17.3 percent of those receiving unstamped envelopes had joined. This significant difference in response rate was considered due to convenience since a $6 membership fee was required of all who joined.

EVALUATION: Brief note indicating the value of return postage.

KEYWORDS: Incentive: postage.

135. Reid, Seerley
1942. Respondents and nonrespondents to mail questionnaires. Educ. Res. Bull. 21(4): 87-96.

School principals (3,293) were contacted by questionnaire to determine the extent of audio-visual equipment being used, and 42 percent responded initially. Special delivery letters and telephone calls to 92 names randomly selected from the remaining (1,032) nonrespondents increased response 69 percent. The replies of the 87 that answered were assumed to be representative of the nonrespondents. On nine out of the 10 questions, there were statistically significant differences between respondents and nonrespondents. Differences reflected less interest in topic by nonrespondents and indicate that respondents are not representative of nonrespondents. Every questionnaire study should include a followup. Nonrespondents can be sampled rather than resurveyed in total. Review of previous studies of nonresponse bias.

EVALUATION: Good example of nonresponse bias. Extent of bias may have been greater with some other topic.

KEYWORDS: Bias: nonresponse
Followup: mail, telephone.

136. Reuss, Carl F.
1943. Differences between persons responding and not responding to a mailed questionnaire. Am. Sociol. Rev. 8(4): 433-438.

Differences between student respondents and nonrespondents to a mail questionnaire were analyzed for differences in (1) intelligence, (2) length of stay in college, (3) community backgrounds, (4) family backgrounds, and (5) social participation. Intelligence and amount of college were positively related to response. Students from rural backgrounds responded more than those with urban backgrounds. Farm children responded better than children of skilled laborers. Sorority and fraternity members responded more than nonmembers. Initiative and strength of ties to the school (interest) generally increased returns.

EVALUATION: Dated article that supports differences between nonrespondents and respondents.

KEYWORDS: Bias: nonresponse.

137. Robin, Stanley S.

1965. A procedure for securing returns to mail questionnaires. Sociol. & Soc. Res. 50(1): 24-35.

A literature review indicates differences between respondents and nonrespondents when the study is concerned with opinions, values, and psychological characteristics but no difference when the questionnaire deals with preference and behavior. Incentives such as money or registered letters rarely increase returns to interview levels. Author suggests a maximum of five contacts with respondents: a prequestionnaire letter, a questionnaire with cover letter, a followup letter, a second questionnaire, and a third followup letter. Content of cover letter is suggested along with a mailing interval of 7 days. Results from nine questionnaire studies show no basis for concluding that prequestionnaire letters made significant differences in returns.

EVALUATION: Excellent literature review and discussion of questionnaire returns. Interpret with caution the nine studies because eight deal with student respondents who may not be representative of other respondents.

KEYWORDS: Cover letter
Bias: nonresponse
Followup: mail
Prequestionnaire letter
Literature review
Incentive: money.

138. Robinson, R. A.

1952a. How to design a mail survey. Printers' Ink 239(9): 27-30.

Planning and construction of the mail survey include: (1) obtain background on the subject; (2) prepare a preliminary list of questions; (3) design the sample to be representative of the population; (4) use accurate, complete, and adequate lists or files, which are current and not subject to duplication; (5) pretest the questionnaire by either direct mail to the respondents or by personal interviews; (6) carefully check the questionnaire before mailing to avoid coding and tabulating bottlenecks; and (7) send along a collated sample of all enclosures to insure proper mailing.

EVALUATION: Brief cookbook outline of questionnaire construction. Excellent for the beginner.

KEYWORDS: Questionnaire: design.

139. _____

1952b. How to boost returns from mail surveys. Printers' Ink 258(June): 35-37.

A variety of procedures designed to increase the probability of questionnaire returns from mail surveys are briefly discussed. The author points out that response rates can be increased by properly designing the questionnaire itself; providing monetary inducement for its completion; including a warm, friendly letter of introduction; providing a stamped, return envelope; and sending several followup letters and at least one additional questionnaire to

nonrespondents. The author points out that, with proper precautions, response to mail questionnaire studies can be increased appreciably above what would otherwise be expected. Data are presented which demonstrate that nonresponse bias is unimportant when the return rate exceeds 80 percent.

EVALUATION: Although much has been learned about mail questionnaires since this paper was written, the major problems associated with constructing questionnaires and prompting their return are well summarized.

KEYWORDS: Questionnaire: design
Incentives: money, motivation, postage
Followup: mail
Cover letter.

140. _____, and Philip Agisim
1951. Making mail surveys more reliable. J. Marketing 15: 48-56.

A men's wear survey of 5,960 subscribers to a leading national magazine showed a 93-percent return after a 25-cent inducement was given in the original questionnaire and a $1 tie clasp was offered in a followup reminder. No significant difference was found between the responses before and after the followup. Authors conclude that when returns reach 80 percent, reliability of data is little affected by nonrespondents. In the followup, a question was included to determine why people had not responded. Almost half said they mislaid it or overlooked answering, and only 7 percent refused outright. This finding indicated the importance of followup mailings with an additional questionnaire included. The authors examined several studies that had high return rates to determine factors that may be helpful in conducting questionnaire studies. These include: preliminary study of the survey population; pretesting questionnaires to discover bias or ambiguities; careful design and format of questionnaire; inclusion of some sort of incentive for respondents; inclusion of a cover letter; inclusion of a return envelope preaddressed and stamped; and the use of followup reminders. In nine studies, the daily returns showed that 50 to 60 percent of the total returns come within 7 days, 90 percent after 2 weeks, and nearly all questionnaires should be received after 3 weeks.

EVALUATION: Excellent paper that corresponds to the objectives behind this annotated bibliography. Three references.

KEYWORDS: Bias: nonresponse
Followup: mail
Cover letters
Pretest
Questionnaire: design, format
Incentive: reward
Early vs. late response.

141. Roeher, G. Allan
1963. Effective techniques in increasing response to mailed questionnaires. Publ. Opin. Quart. 27: 299-302.

A 32-item attitude and information scale was sent to 400 subjects living in both rural and urban areas who had donated to Easter seals and the March of

Dimes. One-fourth of the cover letters gave no title to the endorser and the remainder had a fictitious title, "Director of Rehabilitation," after the name. Of those who received questionnaires with a title, 81 percent returned them; of those without a title, 55 percent. Also, urban residents responded better (83 percent) than rural subjects (72.3 percent).

EVALUATION: Findings are suggestive but lack rigorous analysis to determine significance and amount of variation due to the various factors. Lack of evaluation of nonresponse further weakens results. 12 references.

KEYWORDS: Cover letter
Bias: nonresponse.

142. Rollins, Malcolm
1940. The practical use of repeated questionnaire waves. J. Appl. Psychol. 24(6): 770-772.

In a study by *Cosmopolitan Magazine* to determine for advertising purposes whether their readers traveled by commercial airlines, 750 questionnaires were sent to subscribers. Initial returns were less than 23 percent, and 13 percent of a followup wave were returned. Seventeen percent of the original respondents had flown compared with only 7 percent of the followup respondents. Respondents under age 55 were interested in lower cost, and respondents over 45 interested more in safety.

EVALUATION: Interesting example of how nonresponse bias can affect results.

KEYWORDS: Bias: nonresponse
Followup: mail
Incentive: motivation.

143. Rosen, Hjalmar, and R. A. Hudson Rosen
1955. The validity of "undecided" answers in questionnaire responses. J. Appl. Psychol. 39(3): 178-181, illus.

A questionnaire to union members was supplemented by interviews with a sample of nonrespondents to determine whether responses in the "undecided" category can be considered as valid evidence that individuals have not made definite judgments. Opinion items consisted of statements on norms, perceptions, and evaluations. Findings for the undecided group, that indicated definite perceptions, cast considerable doubt on the validity of middle category (undecided, uncertain) responses. In no case was the undecided group both significantly less homogeneous than the satisfied group and significantly more homogeneous than the dissatisfied group. The "undecided" judgments of members who did not know what was being done on any point would appear to be valid. There is no evidence for the validity of other undecided responses. It may be advantageous to omit the undecided category. Respondents undecided because of insufficient information could leave the question blank, but others may be lured into taking a stand.

EVALUATION: Excellent paper worth considering when designing questions containing "undecided," "don't know," "no comment," or "neutral."

KEYWORDS: Validity
Interpretation
Question: wording.

144. Rosen, Ned A.

1960. Anonymity and attitude measurement. Publ. Opin. Quart. 24: 675-679.

In a preliminary investigation of the effectiveness of the developmental reading program at Purdue University, 678 first-semester college freshmen completed two questionnaires. Half of the students were requested to sign their names and half were not. Identification of respondents in attitude questionnaire surveys conducted under less than highly threatening circumstances is not likely to result in serious statistical or practical distortion. This position is supported by eight of 10 studies cited. Where respondent identification is essential for correlational or followup purposes, the straightforward approach is preferable to a number coding system. In sensitive issues or where there is expected distortion, it may be advisable to use an anonymous questionnaire.

EVALUATION: Caution is advised in extending results of this study to studies involving other age groups who may react differently to signing their names.

KEYWORDS: Anonymous respondent
Questionnaire: design.

145. Rosenau, James N.

1964. Meticulousness as a factor in the response to mail questionnaires. Publ. Opin. Quart. 28: 312-314.

A short questionnaire asking for name, home address, organizational affiliation, phone number, and availability for volunteer work was given to 1,067 national leaders attending a White House conference on foreign aid. Only 32.4 percent were returned. It was hypothesized that idiosyncratic differences rather than interest or involvement in conference topic distinguished respondents and nonrespondents, and that those who returned the questionnaire would more likely respond to a mail questionnaire. A second questionnaire was mailed to the same 1,067 conferees after they returned home. Of the 61 percent who returned questionnaires, a significant 75.1 percent of those who returned the first questionnaire responded. Of those who did not respond to the first questionnaire, 51.6 percent responded to the second one. Cross-tabulation revealed that interest and involvement in the topic was not associated with rate of return. Author concludes that response to surveys is a function of the respondent's habits and attitudes that are highly personal and deeply ingrained.

EVALUATION: Short but interesting paper pointing to an inherent weakness in the use of mail questionnaire.

KEYWORDS: Bias: nonresponse
Incentive: motivation.

146. Roslow, Sydney, and Albert B. Blankenship

1939. Phrasing the question in consumer research. J. Appl. Psychol. 23(5): 612-622.

Included in nine principles considered in the phrasing of questionnaire items are rapport, nonambiguous and concrete questions, question's position in the schedule, importance of respondents' background, nonemotional and unbiased questions, and possible influence of multiple choice-type questions.

EVALUATION: Clear statement of sound principles, still timely.

KEYWORDS: Question: wording.

147. Ruckmick, Christian A.
1930. The uses and abuses of the questionnaire procedure. J. Appl. Psychol. 14(1): 32-41.

Five weaknesses of the questionnaire are given: (1) It stresses explicit categorical answers, (2) it does not account for individual reactions, (3) its results may depend upon the researcher's interpretation, (4) its statistical treatment is often misleading, and (5) nonresponse and the percentage of replies left blank can seriously affect findings. Three advantages of questionnaires are given: (1) large amounts of data can be gathered in a short time, (2) insights can be gained by its exploratory approach to problems, and (3) whoever constructs a questionnaire is forced to define his problem and the implications at the onset.

EVALUATION: Advances during last 40 years make disadvantages seem less serious and advantages obvious.

KEYWORDS: Disadvantages of questionnaires
Advantages of questionnaires.

148. Rugg, Donald
1941. Experiments in wording questions: II. Publ. Opin. Quart. 5: 91-92.

A simple experiment on question wording indicates that alternate word forms may result in different response patterns among certain socioeconomic groups.

EVALUATION: The findings are not definitive, however; and no recommendations are made by the author.

KEYWORDS: Question: wording.

149. Rushmore, Elsie M.
1934. How to get results in mail questionnaires. Printers' Ink 166(March): 17-21.

As a basis for evaluating questionnaire construction, 24 questions are given; and 14 additional questions are given to evaluate reports based upon the findings of questionnaire studies. States that questionnaires are more reliable for quantitative factual data and interviews more reliable for subjective personal data. Weather favors questionnaires over interviews since poor weather makes standing on the doorstep impractical, but good weather decreases the number of people at home.

EVALUATION: Logical, general guidelines reflecting the era in which they were written.

KEYWORDS: Questionnaire: design
Mail questionnaire vs. interview.

150. Russell, Susan D., Robert Konrad, and Arnold D. Kaluzny
1970. Influencing the respondent: an experiment in maximizing the response rate of mail questionnaires. Sociol. Abstr. 18(3): 22.

Mail questionnaires were sent to 623 hospital administrators to test the effect of three mailing conditions: postage--regular, airmail, or airmail-special

delivery; presence or absence of postscript; and presence or absence of "personal" stamped on the envelope. None of the variables had a direct effect, but a combination of airmail-special delivery, a postscript, and "personal" marked on the envelope brought in a 92-percent return. Only 67-percent return was realized from the combination of airmail, no postscript, and no "personal" stamped on the envelope. The highest response was from the closest area from questionnaire origin. The organizational size was related to response rate with the smallest hospitals having the lowest return rates.

EVALUATION: The article is a very brief description of a study with no discussion of findings.

KEYWORDS: Incentive : postage, motivation.

151. Salisbury, Philip

1938. 18 elements of danger in making mail surveys. Sales Manage. 42(Feb.): 28-30, 84-85.

Chances for misinformation and misinterpretation are greater for mail surveys than for interviews. Handicaps of mail surveys include: they take too much of respondent's time; mailing lists are inaccurate; surveys take too long to complete and are more costly than assumed; certain answers are inaccurate when written; nonresponse is high; representativeness is questionable; person sampled may not be the one who answered questions; response is highest for those most interested; negative opinion holders are most likely to respond; incomplete questionnaire is more likely; income is likely to be overstated for prestigious reasons; there is no chance to qualify unclear questions and no chance to evaluate subjectively respondent's mood.

EVALUATION: Handicaps largely overcome through more refined questionnaire design and sampling techniques. Many handicaps listed were poorly supported.

KEYWORDS: Bias: nonresponse
Disadvantages of questionnaires
Mail questionnaire vs. interview.

152. Schwirian, Kent P., and Harry R. Blaine

1966. Questionnaire return bias in the study of blue-collar workers. Publ. Opin. Quart. 30: 651-653.

Analysis of questionnaire returns from the study of members of the United Automobile Workers Union gave significant information on the nature and direction of questionnaire return bias. Three hypotheses were explored: (1) that questionnaire return bias is characteristic of blue-collar populations, as of other populations; (2) that the direction of the bias is predictable; and (3) that the nature of the associations among the variables is not disturbed by the bias. Initial respondents (26.5 percent) to a mailed questionnaire were examined separately from those who responded to a second mailing (27.0 percent). The data lent support for the first two hypotheses. For the third, however, contradictory evidence was found. Not only does return bias have a serious effect upon the estimation of population parameters, but the findings suggest that the association between two variables may be affected.

EVALUATION: The authors properly conclude that researchers not only must

strive to obtain the maximum possible returns to mailed questionnaires but must be sensitive to the subtle effects of return bias.

KEYWORDS: Bias: nonresponse.

153. Scott, Christopher

1961. Research on mail surveys. J. Royal Statist. Soc. 124(2): 143-205.

Five mail surveys by the British Government are examined along with the literature on mail questionnaires. Experimental features introduced into these studies allow measurement of nonresponse bias, early versus late questionnaire returns, response by nonaddressees, the influence of a variety of factors on the response rate, and response reliability and validity. An attempt is also made to evaluate all published research on each topic. 120 references.

EVALUATION: Excellent state-of-the-art compilation.

KEYWORDS: Bias: nonresponse, representativeness
Early vs. late response
Literature review
Followup: mail
Questionnaire: length
Cover letter
Incentive : postage.

154. Scott, Frances Gillespie

1957. Mail questionnaires used in a study of older women. Sociol. & Soc. Res. 41: 281-284.

To ascertain the relationship between personal adjustment in old age and occupational mobility, the author sent questionnaires to 360 women, 60 years of age and older, randomly selected from poll-tax exemption lists. The sample was divided into four parts to test the usefulness of mailing time and the use of a preliminary letter explaining the study. Earlier responses were received when the questionnaire was delivered early in the week, but the ultimate response rate after followup was significantly higher for questionnaires mailed later in the week. A chi-square test revealed no difference in ultimate responses between those receiving and those not receiving a preliminary letter. The preliminary letter may have increased interest and caused respondents to reply promptly. Apparently the followup letter had a similar effect on those who did not receive the preliminary letter.

EVALUATION: Excellent but brief paper on a topic generally underestimated--timed mailing.

KEYWORDS: Followup: mail
Prequestionnaire letter
Incentive: postage.

155. Seitz, Richard M.

1944. How mail surveys may be made to pay. Printers' Ink 209(Dec.): 17-19, 96, 98, 99, 102.

Advantages of direct mail questionnaires are enumerated as well as their disadvantages. Primarily directed to readers wishing to use questionnaires

commercially. "Non-white collar groups are not regarded as good possibilities since they are often unaccustomed to writing." Suggestions on form, wording, cover letter are made as well as ways to increase returns.

EVALUATION: Casual, offhand advice, much of which is misleading; methodology is unsound.

KEYWORDS: Questionnaire: design
Advantages of questionnaires.

156. Selltiz, Claire, Marie Johoda, Morton Deutsch, and Stuart W. Cook
1959. Research methods in social relations. 622 p. New York: Holt Rinehart & Winston.

Chapters 7 and 10 and Appendix C pertain to mail questionnaires. Discussed are problems of validity, questionnaires versus interviews, question content, type of questionnaires, and scaling. Questionnaire construction includes: (1) deciding what information is needed, (2) deciding on the type of questionnaire and writing the first draft, (3) reexamining and revising questions, (4) pretesting, (5) editing questionnaire, and (6) specifying procedures for its use.

EVALUATION: Systematic and thorough discussion of the basic principles of questionnaire construction and use. Worth consulting.

KEYWORDS: Questionnaire: design
Mail questionnaire vs. interview
Advantages of questionnaires
Scaling
Disadvantages of questionnaires
Question: content
Pretest
Textbook.

157. Shafer, Elwood L., Jr., and John F. Hamilton, Jr.
1967. A comparison of four survey techniques used in outdoor recreation research. USDA Forest Serv. Res. Pap. NE-86, 22 p., illus. Northeast. Forest Exp. Stn., Upper Darby, Pa.

Handout questionnaires and mailed surveys--with three to four waves for nonrespondents--provided results that were comparable to personal interview data in 75 to 87 percent of the question items. Delayed mail surveys conducted 3 months after the camping experience,with questions of the same type or of similar complexity as those in the present study, are recommended over handout or immediately mailed surveys.

EVALUATION: Good example of various techniques used in questionnaire research.

KEYWORDS: Advantages of questionnaires
Mail questionnaire vs. interview.

158. Shannon, J. R.
1948. Percentages of returns of questionnaires in reputable educational research. J. Educ. Res. 42(2): 138-141.

A total of 639 research studies in master's theses, Ph.D. dissertations,

and articles in the *Journal of Educational Research* using questionnaires were examined to determine their rate of returns. The mean percentage of returns for the 433 usable studies was 72 percent, but 206 studies lacked enough information to compute returns.

EVALUATION: Article is very generalized but does point out inadequacies in research report writing.

KEYWORDS: Bias: nonresponse
Literature review.

159. Sharp, Harry

1955. The mail questionnaire as a supplement to the personal interview. Am. Sociol. Rev. 20(6): 718.

Survey was made of demographic and economic information on 2,556 adults in a Detroit area survey. Questionnaires were left at each household where any adult contacted could not supply the information needed on adults who were not present. The mail questionnaires were used only to a limited extent, but 40 percent or 21 of the 53 respondents for whom questionnaires were left did return the forms. The use of the mail questionnaire as a supplement to the personal interview did result in a more complete collection of data with comparatively little additional effort on the part of the researchers.

EVALUATION: Good example of the use of questionnaires to supplement an interview survey. Nonresponse was extremely high which reduced the reliability of the questionnaire portion of the study.

KEYWORDS: Applications
Mail questionnaire vs. interview.

160. Shuttleworth, Frank K.

1931. A study of questionnaire technique. J. Educ. Psychol. 22(Dec.): 652-658.

A six-item questionnaire evaluating the effectiveness of a rural public health project was sent to 608 persons with a 25-cent coin enclosed, and to 376 persons with no coin enclosed. There was 52-percent response from those who received the coin but only 19-percent response from the no-coin sample. Coin questionnaires were 12 percent more expensive in terms of unit cost per return.

EVALUATION: The value of money incentive is illustrated, but serious nonresponse may still exist in the 52-percent return. Extensive followup reminders inducing higher returns may be cheaper.

KEYWORDS: Incentive: money.

161. _____

1941. Sampling errors involved in incomplete returns to mail questionnaires. J. Appl. Psychol. 25(5): 588-591.

To test sampling errors due to incomplete questionnaire returns, great effort was invested in securing complete returns in a survey of the employment status of 327 chemistry graduates. Results after 60 percent (184 questionnaires) were returned showed 0.5 percent were unemployed. After another 125 questionnaires were received, the unemployment rate was 5.6 percent; but after

100-percent return, the unemployment rate stood at 4.0 percent. Suggests securing complete returns from at least a portion of the total population in a pretest to aid planning to help minimize sampling errors.

EVALUATION: Concise article demonstrating possible bias resulting from nonresponse to mail questionnaires.

KEYWORDS: Bias: nonresponse
Pretest.

162. Simon, Raymond
1967. Responses to personal and form letters in mail surveys. J. Adver. Res. 7(1): 28-30.

Two readership studies of industrial company magazines and a study of subscribers' attitudes toward a hospital insurance plan provided an opportunity to compare the effects of a personally typed cover letter and a mimeographed form letter. In all three studies, 2,414 questionnaires were sent out to employee readers and general public readers. Questionnaire returns ranged from 26 percent to 60 percent. Results indicate that personally typed letters have no clear-cut advantage over mimeographed form letters in terms of percent response.

EVALUATION: The author's opening statement that "a form letter produced greater returns than a personal letter" is contrary to his results. The nonresponse level in all three studies is extremely high. Eight references.

KEYWORDS: Cover letter.

163. Sjoberg, Gideon
1954. A questionnaire on questionnaires. Publ. Opin. Quart. 18: 423-427.

Two census tracts in Texas were surveyed to determine what attitudes people have toward questionnaires and interviewing. Both tracts were predominantly "Anglo-American," but one had high income and education; the other had low income and education. More people in tract 1 (72 percent) had heard of the Gallup, Belden, and Roper polls than had persons in tract 2 (17 percent). Eighty-three percent of the respondents in tract 1 and 70 percent in tract 2 believed that people should be asked their opinions about political and social problems. Most people were opposed to having the city exercise restraint on interviewing. However, only 52 percent in tract 1 and 38 percent in tract 2 favored having interviewers come to their homes. Little more than half the people preferred personal interviews to mailed questionnaires or telephone contacts. Interviewees were more willing to answer questions concerning religious beliefs and their jobs than to answer questions about money matters, political beliefs, and family life. In tract 1, 78 percent, and in tract 2, 55 percent responded with "Yes" when asked, "Do you believe most people answer honestly the questions they are asked by the interviewers?"

EVALUATION: Interesting findings on type of questions respondents like and dislike most. Survey oriented toward interviews but has application for mail questionnaire surveys.

KEYWORDS: Mail questionnaire vs. interview.

164. Sletto, Raymond F.
1940. Pretesting of questionnaires. Am. Sociol. Rev. 5(Apr.): 193-200.

Over 6 months were spent pretesting a questionnaire to be sent to 1,600 former university students. Length of questionnaire did not significantly affect the response rate of a 10-, 25-, and 35-page questionnaire in a 300-member pretest group. Three different cover letters did not significantly affect the rate of return. One cover letter requested help on an altruistic basis, another on a challenge basis, and a third on a "help us" basis. To test post-card versus letter followup notices, half of the nonrespondents from above received the post card and the other half, the letter. The number of returns was identical for each method. A third test involved recipients of the 25-page questionnaire who were asked to check difficult, dull, or unrelated sections of the questionnaire. Twenty-two of the 60 respondents reacted unfavorably to questions relating to problems in the communities. These questions were rearranged with other, more favorable questions so their impact would be reduced. Another test asked 47 students to rate the esthetic appearance of 10 different page formats. Results indicate that esthetic preferences are not highly individualistic nor erratic. The final questionnaire containing 52 pages yielded 69-percent return. Author concludes that greater attention should be directed at pretesting to discover the selective factors that will bias the final questionnaire.

EVALUATION: Excellent study demonstrating the importance of pretesting. Well worth reading before starting a questionnaire study.

KEYWORDS: Cover letter
Pretest
Followup: mail
Question: type
Questionnaire: format, length.

165. Slocum, W. L., L. T. Empey, and H. S. Swanson
1956. Increasing response to questionnaires and structured interviews. Am. Sociol. Rev. 21(2): 221-225.

Results of four studies involving farmer-hunter relationships, occupational planning of high school seniors, consumer habits, and college student withdrawals show that efforts to establish an image of the social utility of a survey and to emphasize the special role of each respondent will maximize response. Improvising and designing approaches to fit specific situations are necessary for utilizing these principles.

EVALUATION: High response case studies used to support hypothesis. Poor control over other variables that probably contributed to response rate.

KEYWORDS: Incentive: motivation.

166. Smith, Francis F.
1935. The direct validation of questionnaire data. Educ. Admin. & Superv. 21(8): 561-575.

In an analytical inquiry into the validity of questionnaire data, various studies showed that individual response, taken by itself, is questionable. Individuals differ in their ability to furnish valid data such as estimates of size, number,

time, speed, and so on, particularly under rigorous standards. Validity is increased by increasing the sample size and merging their responses. In no case studied does the validity of questionnaire data seem to meet the rigorous demands made by more precise sciences. The validity of responses involving judgment and opinion is usually lower than for responses involving factual data. But factual data involving personal accomplishment often has prestige bias.

EVALUATION: Dated but good basic data presented with analytical support.

KEYWORDS: Validity
Literature review.

167. Smith, Mapheus
1933. A note on stability in questionnaire response. Am. J. Sociol. 38(5): 713-720.

Fifty college students were given a 60-item questionnaire dealing with factual family items, factual personal items, and subjective personal items. Four months later they retook the questionnaire, and 780 answers were different. Average change per person on 16 family items was 4.0 questions for 22 males, and 3.1 for 28 females. Changes in 19 factual personal items were 4.3 for males and 3.5 for females. Changes in 25 subjective personal items were 10.0 for males and 6.9 for females. Forty-six of the students changed 10 or more items each.

EVALUATION: Many items reported may have logically changed in the intervening 4 months of study. For example, "Are you engaged?" "Age of mother," or "Do you dream often?"

KEYWORDS: Reliability.

168. Stanton, Frank
1939. Notes on the validity of mail questionnaire returns. J. Appl. Psychol. 23(1): 95-104.

A three-page mail questionnaire concerning the use of classroom radio facilities was sent to 11,169 U.S. schoolteachers, and 28.3 percent were returned. Results showed that the first half of the respondents' answers did not differ significantly from the last half, and the first 95 percent to respond did not differ from the last 5 percent. After 5 days, 43.5 percent of the total responses had been received. Another sample of 4,942 teachers was sent the same questionnaire; however, a followup questionnaire was sent on the 17th day after the original mailing. This time, 50.2 percent responded, and results showed a much higher proportion of teachers who did not use the radio facilities. These two examples indicate that the use of followup technique produces a significant increase in returns and gives a more representative sample in that people who were less interested or believed they had little to contribute were stimulated into responding.

EVALUATION: This is one of the few actual tests of the effects of followup to stimulate response. In addition, the author claims to have received a 94-percent return using three followup contacts in another study.

KEYWORDS: Followup
Bias: nonresponse
Early vs. late response.

169. Stephan, Frederick F.

1948. History of the uses of modern sampling procedures. Am. Statist. Assoc. J. 43(241): 12-39.

An extensive history of sampling is presented. Empirical knowledge is derived from incomplete observation and is a sampling of experience. Principles of sampling emerged from common sense, custom, and experience arising from needs of agriculture crop estimates, economic statistics, statistical phases of social and health surveys, and public opinion polling. Probability theory, though well established in the 18th century, was not applied until the 20th with statistical needs of the government increasing during the depression. Complex sampling systems have been designed to fit the sample population, the costs and administrative factors, and the principles of efficient design. Sampling choices are based on the study purpose, knowledge of the material, and experience with previous studies. Most current opinion polls and market research studies employ quota methods. The second war has been a greater accelerating stimulus to sampling than the depression of the 1930's.

EVALUATION: Excellent historical perspective of survey research in general. Questionnaire research as such is not stressed.

KEYWORDS: Literature review
History
Applications.

170. Stoke, Stuart M., and Harvey C. Lehman

1930. The influence of self-interest upon questionnaire replies. Sch. & Soc. 32(822): 435-438.

Studies of individual members of seven classes on educational psychology lead to one conclusion: It is naive to assume that the lazy student would give an accurate report of his own laziness. Probably little reliance can be placed on students' statements of how much they study.

EVALUATION: Dated, but points to problem of soliciting self-evaluation on sensitive subject.

KEYWORDS: Reliability
Incentive: motivation
Bias: stated vs. actual behavior.

171. Suchman, Edward A.

1962. An analysis of "bias" in survey research. Publ. Opin. Quart. 26: 102-111.

Given the fact that nonresponse does introduce a bias, an important question is not only "Are the data biased?" but also "How does the presence of bias affect the relationship between variables?" Despite a biased frequency distribution of interest and education in a panel study, the interrelationship between education and interest was not affected by this biased sampling. Another panel study found that even though educated people respond more, they did so regardless of whether they were Catholic or Protestant. The presence of this bias did not affect the relationship between education and religion. The differential effect of bias appears to be a key factor in evaluating the importance of bias.

If a bias is constant (e.g., all educated people respond more regardless of interest, and vice versa), then the biased and unbiased samples will show the same results. However, if the bias is differential (e.g., the uninterested educated people and the interested uneducated people respond more), then the respondent and nonrespondent may differ. Finally, when the emphasis is upon the phenomenon being studied and not upon its distribution in the general population, bias may be used intentionally to one's advantage.

EVALUATION: Good perspective of bias with a rigorous approach to it.

KEYWORDS: Bias, nonresponse
Validity.

172. _____ and Louis Guttman
1947. A solution to the problem of question "bias." Publ. Opin. Quart. 11: 445-455, illus.

Presents an objective method of dividing respondents into pro and con groups which are relatively independent of question wording. The procedure for eliminating question "bias" consists of: (1) asking many questions on the same topic; (2) determining by scale analysis whether questions ask the respondent about the same dimension of opinion; (3) asking "How strongly do you feel about this?" after each opinion question; (4) relating content of opinion to intensity of feeling. This determines the zero or neutral point for content. The theory that the same intensity curve will be obtained by any sample of questions from the same scale can be tested by taking two series of opinion questions on the same topic which are biased in opposite directions and determining if the intensity measurement serves to correct these biases. Two examples illustrate this study.

EVALUATION: Excellent paper backed with objectivity. A must for those constructing scale-type questions.

KEYWORDS: Questionnaire: design
Question: wording
Scaling.

173. _____ and Boyd McCandless
1940. Who answers questionnaires? J. Appl. Psychol. 24(6): 758-769.

Two studies involving radio listeners each received response rates of over 95 percent. In the first study, original mail questionnaires were followed by a second followup, and finally by a telephone contact of nonrespondents. In the second study, the original questionnaire was followed by three followup questionnaires with the last questionnaire simplified and shortened to contain only key questions. Two main factors were found to influence the returns: interest or familiarity with the topic under investigation--the more interest, the greater the returns; and education of the respondent--the better educated, the greater the returns. For the analysis, respondents of the original questionnaire were compared with those responding to followup questionnaires. A biasing effect would have occurred if the researchers had not sent followup questionnaires.

EVALUATION: Good example of the value of followup contacts with study subjects.

KEYWORDS: Bias: nonresponse
Early vs. late response
Followup: mail, telephone.

174. Tallent, Norman

1959. A note on an unusually high rate of returns for a mail questionnaire. Publ. Opin. Quart. 23: 579-581, illus.

A total of 1,567 mimeographed questionnaires with a covering letter of explanation were mailed to 393 psychologists, 741 psychiatrists, and 433 social workers, all employees of the Veterans Administration, as part of a study on the preparation of clinical reports. Completed forms were returned by 384 psychologists (97.7 percent), 602 psychiatrists (81.2 percent), and 421 social workers (97.2 percent). Three solicitations for cooperation were made: the initial questionnaire and a first and second followup letter. A personal cover letter and a postage-free return envelope also increased response. The questionnaire form had brief directions, a simple method of indicating choice of response, and space for comment. Establishment of a deadline and the enclosure of a duplicate questionnaire after the second followup letter also may have increased returns.

EVALUATION: Return rate most likely due to professional commitment; study lacks rigorous analysis.

KEYWORDS: Cover letter
Questionnaire: design
Bias: nonresponse
Incentive: motivation, postage.

175. Toops, Herbert A.

1923. Validating the questionnaire method. J. Personnel Res. 2(4&5): 153-169, illus.

Five followup letters gave 93-percent returns from 93 trade school graduates. Graphs show number and timing of returns resulting from each followup. The cost per return decreased as the number of returns increased. Questionnaires arriving at the recipients' homes on Friday and Saturday were answered more often than ones arriving at the beginning of the week. Plotting a cumulative curve of daily returns can indicate when followup letters should be sent. Copies of all followup letters included.

EVALUATION: An excellent example of the use of followups.

KEYWORDS: Followup: mail
Incentive: postage.

176. _____

1926. The returns from followup letters to questionnaires. J. Appl. Psychol. 10(1): 92-101.

Six followup letters resulted in 100-percent return from 110 questionnaires sent to college administrators asking about their use of intelligence tests. The relationship between use or nonuse of the tests and the number of followups required was examined to determine what caused the recipients to delay responding to the questionnaire. Recipients who knew the sender replied sooner than strangers. All followup letters are illustrated.

EVALUATION: Excellent example of effect of persistent followup.

KEYWORDS: Followup: mail.

177. _____

1935. Predicting the returns from questionnaires: a study in the utilization of qualitative data. J. Exp. Educ. 3(3): 204-215.

Multiple regression analysis of two questionnaire investigations was used to determine which of 17 questionnaire characteristics were most closely related to maximum returns. Questionnaire factors which had the highest zero-order correlation with percentage of returns include questionnaire subject; number of copies issued; address of questionnaire sender; ease of answering questions; type of question asked (yes-no, short answer, or long answer); objective or subjective answers requested; and title of questionnaire sender.

EVALUATION: Poorly written; conclusions weakened by presenting a summary of "seemingly important elements . . . which go beyond our data" and are plainly labeled as a "guess." However, the factors can be used as pointers in questionnaire construction.

KEYWORDS: Questionnaire: design
Incentive: motivation.

178. _____

1937. The factor of mechanical arrangement and typography in questionnaires. J. Appl. Psychol. 21(2): 225-229.

The questionnaire should be viewed as a stimulus for achieving a particular end result, and in its construction other considerations must be subordinated to that purpose. Rules of rhetoric are important only inasmuch as they make questions more clear. Redundancy may be useful. Illustrated is the use of certain capitalized words of a sentence so that an idea can be obtained at a glance of the capitalized portions. This facilitates both the respondent and the evaluator.

EVALUATION: Theoretically sound idea, worth considering when constructing questions.

KEYWORDS: Questionnaire: design
Question: wording.

179. Vernon, P. E.

1939. Questionnaire, attitude tests and rating scales, p. 199-299. *In* F. C. Bartlett, The study of society. New York: The Macmillan Co.

Sections of this chapter include advantages of the questionnaire, types of questionnaires, criticisms, precautions in applying questionnaires and interpreting results, and the representativeness of results.

EVALUATION: This is a broad overview; if more recent material is unavailable, this text is worth reading.

KEYWORDS: Bias: representativeness
Disadvantages of questionnaires
Interpretation
Textbook.

180. Vincent, Clark E.

1964. Socioeconomic status and familial variables in mail questionnaire responses. Am. J. Sociol. 69(6): 647-653.

Data show that mail questionnaire research appears to elicit a disproportionately high response from subjects whose self-reported backgrounds in "normal" lower-middle-class families skew familial data in the direction of the predominant textbook model of the nice, stable, middle-class family. Data were based on the returns from two California psychological inventory questionnaires sent to 517 senior class students in 1954 and again in 1959. A slight tendency was noted for the cooperative respondents to have a more "socially desirable," conformist personality profile. When the distribution of subjects among three response groups (cooperative, post-card, and no-response) was examined, the cooperative group was most likely to have completed high school and be in clerical and sales level jobs, whereas the no-response group more often had fathers of high educational levels and both high and low occupational levels. The data on intrafamily relationships provided the most impressive trend evidence of bias introduced by respondent-nonrespondent differences. The cooperative group consistently overrepresented positive intrafamily relationships and underrepresented negative relationships. Similarly, the respondent sample overrepresented subjects who in childhood were "verbally disciplined by mother" and underrepresented subjects who were "physically disciplined by father."

EVALUATION: Relevant to mail questionnaire research in general with implications for mail questionnaire research on the family in particular.

KEYWORDS: Bias: nonresponse.

181. Wagner, Isabelle F.

1939. Articulate and inarticulate replies to questionnaires. J. Appl. Psychol. 23(1): 104-115.

In open-end questionnaires, some respondents are more articulate than others. To determine if this articulate minority is representative, 558 women were asked two open-end questions. Answers were rated for articulateness (defined as the total number of words used to reply). Results indicate (1) similar amounts of articulateness to both questions; (2) no relation to age, income, marital status, and husband's occupation; and (3) positive relation of habits and interests of articulate respondents to intellectual training and personality.

EVALUATION: Assumption that articulateness equates to verbosity is questionable. Results are inconclusive.

KEYWORDS: Open-end questions.

182. Waisanen, F. B.

1954. A note on the response to a mailed questionnaire. Publ. Opin. Quart. 18: 210-212.

A sample of 300 TV and no-TV families were randomly selected in Iowa City. Phone calls were made to 175 of these families; of TV owners and nonowners who were phoned prior to the questionnaire mailing, 47.8 and 44.7 percent, respectively, returned the questionnaire within 10 days. The return from TV owners and nonowners who were not phoned was only 28 and 24.5 percent, respectively. Although limited to local research studies, the phone contact technique provides personal contact, elicits the promise of cooperation, and provides an opportunity to emphasize the brevity and simplicity of the questionnaire.

Phone contacts could have been made at the rate of 30 per hour, and of 175, only two refused to cooperate.

EVALUATION: Good example of what personal attention to respondents can do for stimulating returns. With additional prompting and longer time period, greater returns could have been realized.

KEYWORDS: Prequestionnaire letter , contact (phone)
Bias: nonresponse.

183. Wallace, David
1954. A case for -- and against -- mail questionnaires. Publ. Opin. Quart. 18: 40-52.

Two groups were compared: male *Time* magazine subscribers and the male population-at-large in Dayton, Ohio. Four questionnaires were sent successively to each group at intervals of 3 weeks. Approximately the same number of men replied to each mailing, and there was no marked variation in the response rates due to question content. There was little indication of respondent "fatigue" even after four questionnaires. In the "case for" the questionnaire, the authors found that repliers and nonrepliers were almost the same over the four mailings. Typical mail surveys with 15- to 30-percent return rate often assume that the respondents are representative of the entire sample population. This is based upon the idea that for one reason or another some persons answered this time and those who did not will answer the next survey questionnaire. In the "case against" mail questionnaires, the authors found that persons who answered any three or all four questionnaires is greater than the number who might be expected to do so by chance. Also, the number who did not answer any of the questionnaires was greater than chance expectations. In other words, typical mail response consists of upwards of 50 percent of habitual repliers and a disproportionately small number of persons who answer only occasionally. Thus, in surveys with low return rates, the response is rarely representative of the universe being sampled.

EVALUATION: Excellent lesson on representativeness of low response rate surveys. One weakness is the apparent assumption that low return rates are inevitable with mail questionnaires; thus, the author is addressing himself to low return rate surveys and not mail surveys as such.

KEYWORDS: Bias: nonresponse, representativeness.

184. Wang, Charles K. A.
1932. Suggested criteria for writing attitude statements. J. Soc. Psychol. 3(3): 367-373.

The statement must be debatable; all statements on a given issue should belong to the same attitude variable; statements should have only one interpretation; express only one idea; be short; use specific terms; avoid more than one sentence; not infer an attitude but be clear cut and direct; avoid words subject to interpretation such as only, mere, just, large, etc.; and avoid colorless expressions. Sentences should be simple rather than complex or compound. If sentence cannot be simple, make it complex rather than compound; use the active voice; try to use the term of the issue as the subject of the sentence; and avoid

uncommon words, technical terms, negative expressions, double infinitives, redundant phrases, double negatives, and phrases such as "I think . . .," "I believe . . . ."

EVALUATION: Excellent suggestions, highly recommended for anyone constructing questions of any kind.

KEYWORDS: Question: wording
Questionnaire: design.

185. Weilbacher, William M., and H. Robert Walsh
1952. Mail questionnaires and the personalized letter of transmittal. J. Marketing 16(3): 331-336, illus.

A total of 472 letters were mailed to university alumni fraternity members; 46 were returned unclaimed, 184 returns were received, and 242 did not respond. The sample was divided so that half received a personalized letter of transmittal and a control group did not. There was no significant difference between the two groups.

EVALUATION: Poorly written; findings may be questioned due to very low response rate.

KEYWORDS: Cover letter
Incentive: motivation.

186. Wembridge, Eleanor Rowland, and Edger R. Means
1918. Obscurities in voting upon measures due to double-negative. J. Appl. Psychol. 2: 156-163.

Sixteen propositions were expressed in six different ways: simple affirmative, simple negative (with a word like prohibit), simple negative (with the word not), double negative (with words not prohibit), double negative (with prohibit prohibit), and double negative (with not not). Results show that test subjects took much greater time to answer the double negative questions than the simple affirmative ones. In addition, the double negative questions confused respondents as to the true meaning of the question. An example of the double negative is "minors shall not be forced not to smoke."

EVALUATION: Excellent paper on a topic often taken for granted.

KEYWORDS: Question: wording.

187. Whitney, Frank P.
1924. The questionnaire craze. Educ. Rev. 68(Oct.): 139-140.

A barrage of questionnaires were sent to school administrators from irresponsible sources or merely curious parties.

EVALUATION: An interesting commentary on the early misuse of questionnaires.

KEYWORDS: Applications
History.

188. Wiiliams, Allan F., and Henry Wechsler
1970. The mail survey: methods to minimize bias owing to incomplete response. Sociol. & Soc. Res. 54(4): 533-535.

A 20-item questionnaire was sent to 1,695 dentists to determine willingness to expand their practice. Five contacts were made with respondents: preliminary letter, initial questionnaire, followup reminder, second questionnaire, and final followup reminder (each sent at 7-day intervals). Guidelines are presented on presentation, content, and form of the questionnaire. Response rate was 77.8 percent. A telephone followup was conducted on the 440 nonrespondents 1 month later. Results indicate that about 15 percent of the nonrespondents had moved and 20 percent agreed to return the questionnaire. Of the original 358, 64 percent were reached on the first phone call and only 7.5 percent required more than three attempts. Respondents were typically younger specialists who worked fewer weeks per year than nonrespondents. When the telephone contact was treated as nonresponse and compared with earlier respondents, no statistically significant differences were found. Telephone contacts are of value to determine eligible members of the sample and thus raise the response rate, and they also provide some information on nonrespondents.

EVALUATION: Author presents an example of using Robin's system (see Robin 1965) for minimizing bias in questionnaire research.

KEYWORDS: Followup: mail, telephone
Prequestionnaire letter
Questionnaire: design.

189. Wilson, P. W.
1934. A question of questionnaires. N. Am. Rev. 237(4): 325-330.

Essay criticizing questionnaires because they invade the privacy of the individual and can be used to "manage our minds for us." Questionnaires not only yield answers but affect the respondent as well. If psychologists ask questions for the sake of their science, we may expect politicians to ask questions for the sake of their politics.

EVALUATION: Opinions poorly supported.

KEYWORDS: Disadvantages of questionnaires.

190. Young, Pauline V.
1939. Schedule and the questionnaire as aids in field exploration, p. 138-171. *In* Scientific social surveys and research. New York: Prentice Hall.

Instructions for the construction of questionnaires are presented, including suitable topics for maximum utility of the questionnaire, times for use, and suggestions for reducing nonresponse. Gives 11 checks used to evaluate the completed questionnaire.

EVALUATION: Practical; organized to facilitate comprehension of essential points.

KEYWORDS: Questionnaire: design
Applications
Textbook.

191. _____
1956. The questionnaire and other reporting forms as aids in field exploration, chapter VIII, p. 176-204. *In* Scientific social surveys and research. Englewood Cliffs, N.J.: Prentice Hall.

Types of questionnaires are discussed along with aspects of design, communication problems, and bias. Under questionnaire format, the author discusses question arrangement, type used in printing, kind of paper used, margins, spacing, cover letter and followup letters.

EVALUATION: Practical and organized to facilitate comprehension of essential points.

KEYWORDS: Questionnaire: design
Applications
Textbook.

192. Young, R. A., I. I. Holland, and A. R. Gilmore
1970. Getting better returns from mail questionnaires. J. For. 68: 723-724, illus.

A mail questionnaire case study of 500 randomly selected Illinois campers showed an 85-percent return. The high rate of return was attributed to the questionnaire's appearance, simple layout, and wording; a pretest; a personalized cover letter; stamped return envelope; and two followup letters.

EVALUATION: Good practical questionnaire procedures outlined. Article fails to point out importance of sampling nonrespondents to determine if they differ from respondents.

KEYWORDS: Questionnaire: design
Cover letter
Incentive: postage
Followup: mail.

193. Zimmer, Herbert
1956. Validity of extrapolating nonresponse bias from mail questionnaire follow-ups. J. Appl. Psychol. 40(2): 117-121.

A study tests the hypothesis that response-nonresponse probability function indicates the presence and direction of nonresponse bias. Questionnaires were mailed to 220 servicemen; and after one followup and 11 months, 87 percent had been returned. Results indicate that five (age, education, rank, years in service, and occupation) of the seven variables considered were found to be consistent with the hypothesis but failed to attain statistical significance. Marital and military status each contained significant nonresponse bias but was inconsistent with the hypothesis.

EVALUATION: Excellent attempt to predict nonresponse bias. Failure to prove hypothesis may be due to small sample size.

KEYWORDS: Bias: nonresponse
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